Socio-emotional Processing in Children, Adolescents and Young Adults with Traumatic Brain Injury

Submitted by Jac Rhys Dendle, to the University of Exeter

as a thesis for the degree of Doctor of Clinical Psychology, May 2014

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: ……………………………………………………………..

Acknowledgements

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Author's declaration

The study was conducted across three sites, a Young Offenders Team (YOT) and a Targeted Youth Support service (TYS) in the south west of England and in a Her Majesties Prison Young Offenders Institute (HMP/YOI) in London. Data collection was conducted by the author and an MSc student. The main study procedure was designed by the author. Data collection and procedural arrangements at the YOT and TYS was carried out by the MSc student. Data collection and procedural arrangements at HMP/YOI was carried out by the author. Although some of the data collected was used for both an MSc project and Doctorate in Clinical Psychology empirical paper, the research questions and hypotheses of the two studies were different.

Literature Review: The Socio-emotional Processing Stream in Children, Adolescents and Young Adults with Traumatic Brain Injury

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Abstract

Objective: The significance of socio-emotional deficits in children, adolescents and young adults with traumatic brain injury (TBI) has been identified by a number of studies. However, the literature is poorly integrated. This literature review aimed to integrate the evidence base using Ochsner's (2008) socio-emotional processing stream. ***Method:*** The online databases, PsychInfo and Web of Knowledge, were used to search for relevant available papers written in English during available years of publication until 2014. A number of youth, TBI, socio-emotional processing and offender search strings were used. ***Results:*** Twenty one studies were identified, mapping onto three of the five constructs of Ochsner's (2008) model. Children, adolescents and young adults with TBI demonstrated impairments in recognition and response to social affective stimuli, high-level mental state inference and context sensitive regulation (constructs 2, 4 and 5). ***Conclusions:*** This review has highlighted that children, adolescents, and young adults who had a TBI experience a range of socio-emotional processing difficulties. Only some of the identified difficulties can be mapped onto Ochsner's (2008) model and therefore, it may not be a suitable model for socio-emotional processing in this TBI population. Further research is required to increase the understanding of socio-emotional processing for this population and to explore suitable models.

Introduction

Childhood, adolescence and young adulthood[1] have a high prevalence of traumatic brain injury (TBI), making TBI a leading cause of disability (Langlois et al., 2006; Yates, Williams, Harris, Round, & Jenkins, 2006). TBI prevalence rates, of all severities, in the general population have been reported at 5%-24% (McGuire, Burright, Williams, & Donovick, 1998), with a peak risk in adolescences (Yates et al., 2006). Brain injury is typically associated with neuropsychological, psychosocial and behavioural difficulties (Croker & McDonald, 2005).

Recent studies suggest that socio-emotional deficits are prominent when TBI has occurred during childhood and remains persistent throughout development (Eslinger, Flaherty-Craig, & Benton, 2004; Tonks et al., 2009; Turkstra, McDonald, & Depompei, 2001). Evidence indicates that there are many brain structures and considerable overlap involved in socio-emotional processing (Johnson et al., 2005). For example, the prefrontal cortex, anterior cingulate, amygdala, insular, hippocampus, orbitofrontal, temporal, parietal and occipital cortices of the brain have all been associated with verbal and/or visual socio-emotional processes (Beason-Held, Goldski, Kraut, Esposito, & Resnick, 2005; Ochsner, 2008; Haxby, et al., 1991; Tonks et al., 2008). Consequently, socio-emotional processing is particularly susceptible to the crowding effect[2] caused by neuro-plasticity[3] (Anderson Catroppa, Morse, Haritou, & Rosenfeld, 2005). Following early childhood brain injury, neuro-plasticity and recovery may allow a child to make good physical recovery,

[1] Age bands were based on the World Health Organization (1999) categories: under 10 years of age: children; 10-19 years of age: adolescents; 20-25 years of age: young adults.
[2] The preferential neural reorganisation and regeneration following brain injury of certain brain functions (e.g. language) at the expense of other functions (e.g. visuo-spatial) leading to potential developmental limitations (Stiles et al., 2000).
[3] Functional recovery as a result of neural reorganisation and regeneration following brain injury.

receive swift discharge from paediatric follow-up and even return to mainstream school (Tonks et al., 2009). However, deficits involving executive synthesis may remain hidden until later childhood or adolescence (Tonks et al., 2009). An individual who has suffered a childhood brain injury may not have developed the necessary skills to deal with demanding social situations (Tonks et al., 2009). As a result, social problems, such as inappropriate social responses, may begin to emerge. Such actions could be detrimental to social functioning and put an individual at greater risk of socially unacceptable behaviour. This has important clinical implications when considering rehabilitation following childhood, adolescent or young adulthood TBI.

A number of socio-emotional processing models have been developed. For example, based on the child social information and adjustment literature, Crick and Dodge (1994) developed the social information processing (SIP) model involving five distinct cognitive stages that occur in response to a social situation (encoding, representation, response searching, selecting a response, acting). However, social interaction is not just a cognitive process (Ochsner, 2008) and subsequently, Lemerise and Arsenio (2000) revised the SIP model (Crick & Dodge, 1994) to include emotion processing. Tonks et al. (2009) proposed a three stage developmental model of emotion recognition for children and described the potential detrimental effects of childhood TBI within the model. The first stage of Tonks et al's (2009) model is a fast unconscious recognition response that relies on subcortical brain structures (developed from birth). The second is a conscious process of emotion recognition involving more sophisticated cortical subsystems (developed at approximately 18 months old) and the third requires the synthesis of emotion and cognition to guide thought and response (developed throughout childhood). Although the models described above share common themes, none of them combine cognitive, emotional and neurological processes. Lemerise and Arsenio's (2000) model does not consider cortical structures. Tonks et al.'s (2009) model describes the critical phases in childhood social emotional and neurological development, but does not break down and categorise these processes.

Synthesising concepts described in Crick and Dodge's (1994), Lemerise and Arsenio's (2000) and Tonks et al's (2009) studies, Ochsner's (2008) socio-emotional processing model incorporates both affective/unconscious and cognitive/conscious processes and considers the cortical structures involved. Ochsner (2008) used the emerging neural, social and emotional research base to construct a framework. The five constructs of the socio-emotional processing stream are distinct in cognitive process and neural systems (figure 1; Ochsner 2008). According to Ochsner's (2008) model, the constructs lie along a hierarchy of processes in which we: learn the value of a stimulus (construct 1); re-encounter it and recognise its value (construct 2); understand the beliefs and feelings of a stimulus (including oneself) in a bottom-up, experiential (construct 3) or top-down, attributional manner (construct 4); attempt to regulate responses to a stimulus in a context appropriate manner (construct 5).

Although the evidence base is limited, Ochsner's (2008) socio-emotional processing stream appears to create a platform to consider cognitive, emotional and neurological processes together. These are important to consider following brain injury and make it a potentially appropriate model for TBI. The model provides the opportunity to identify and isolate specific socio-emotional processes and it could therefore, facilitate the targeting of specific behaviours and emotional processes that may require intervention. Furthermore, the model's synthesis of the cognitive, emotional and neurological processes may allow the formulation of a heuristic that could enable the identification of gaps in the literature and develop testable hypotheses.

Social functioning (Rosema, Crowe, Anderson, 2012) and emotional development (Tonks et al., 2009) following childhood and adolescent brain injury has been reviewed. However, to the author's knowledge there appears to be no literature review assimilating all the experimental research into a socio-emotional model following childhood, adolescent or young adulthood TBI. This review aimed to identify the TBI socio-emotional literature, integrate the results into Ochsner's (2008) model and test the suitability of the model for the childhood, adolescent and young adult TBI research base.

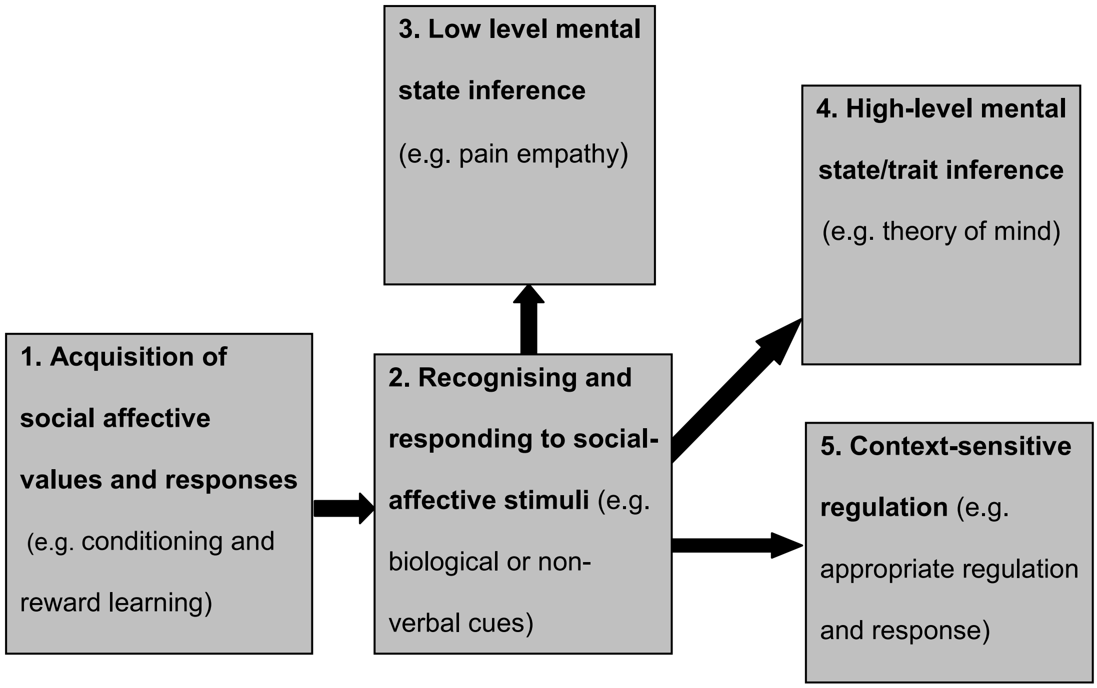

Figure 1: The five constructs of the socio-emotional processing stream (adapted from Ochsner, 2008).

Research Questions

This review has the following research questions:

(1) Is there evidence for socio-emotional processing deficits in children, adolescents and young adults with a TBI?

(2) Can evidence for emotional processing deficits in children, adolescents and young adults with a TBI be integrated into the constructs of Ochsner's (2008) socio-emotional processing stream?

(3) Is Ochsner's (2008) socio-emotional processing stream appropriate for TBI populations?

(4) Can the results of the literature review propose directions for future research and identify potential areas for clinical intervention?

Methods

Eligibility Criteria

For inclusion, studies were required to have:

1. Investigated an aspect of emotional processing or social functioning and/or cognition, using a primarily experimental design. Experimental design was preferred to self-report methods for two reasons: first, Ochsner's (2008) model of the socio-emotional processing stream emphasises experimental research within its design; second, self-report relies on the participant having some level of insight into their deficits, which can be difficult following a TBI (Stancin et al., 2002).
2. Contained a clinical sample of children and/or adolescents and/or young adults (aged below 25 years) who had suffered a TBI.

Information Sources and Search Strategy

The online databases PsychInfo and Web of Knowledge were used to search for relevant available papers written in English during available years of publication until 2014. The search aimed to be broad in order to identify all research investigating socio-emotional processing. The following strings of search terms were used: ("Youth" OR "Juvenile" OR "Adolesc*" OR "Child*") AND ("Head injur*" OR "Brain injur*") AND ("Social*" OR "Emotion*" OR "Affect*" OR "Process*" OR "Alexithym*" OR "Percept*" OR "Theory of mind" OR "Empath*" OR "Regulat*" OR "Express*" OR "Experiment*" OR "Ekman faces" OR "fMRI" OR "Face*" OR "Facial" OR "Mirror*" OR "Recog*") (* indicates truncation; search strings were adapted from Oldershaw et al., 2011). In addition, reference sections from all included papers were inspected and the research supervisor was consulted to identify additional relevant papers (for more information about how papers were selected see the flow chart in appendix 1).

Study Selection and Categorisation

In order to clarify the nature of socio-emotional dysfunction after childhood, adolescent or young adulthood TBI, studies of social and emotional processing with experimental designs have been reviewed. Despite casting a wide net initially, only 21 articles met the review criteria. The studies were categorised and are reported according to the constructs of Ochsner's (2008) socio-emotional processing stream.

Results

Construct 1: Social Affective Values and Responses

The first construct of Ochsner's (2008) socio-emotional processing stream is the development of social affective values and responses, which involve responding to conditioned stimuli and the relating conditioned biases. Ochsner (2008) suggests that the processing of affective stimuli involves the amygdala and striatum. This is supported by research implicating the amygdala in fear conditioning (LaBar et al., 1998) and in discriminating visual social and emotional meanings (Emery et al., 2001).

None of the identified papers related to construct one. However, research in this area could be relevant, especially when considering aggressive behaviour, misconduct and offending following TBI. For instance, studies of aggressive children, without a TBI, have revealed a negative or hostile attribution bias associated with the mislabelling of emotional expressions as angry (Crick & Dodge, 1996). In addition, Leon-Carrion and Ramos (2003) reported that a history of un-treated TBI in childhood or adolescence was associated with sentencing for violent offending in adulthood. It is therefore possible that children and adolescents with a TBI may have a negative or hostile attribution bias towards emotional faces. Consequentially, this may lead to violent behaviour and offending in socially misread situations.

Construct 2: Recognising and Responding to Social Affective Stimuli

Once social-affective values and responses have been learnt for different stimuli, an individual must then be able to recognise and respond rapidly upon its presentation (construct 2). The Amygdala, insula, temporal sulcus, temporal parietal junction and ventromedial prefrontal cortex, are thought to be involved in the process of recognising and responding to social-affective stimuli (Baron-Cohen et al, 2000; Marsh & Blair, 2008). Difficulties with facial affect recognition in children and adolescents with autistic spectrum disorder (ASD) have been linked to social deficits and perceived behaviour difficulties (Rose et al., 2007).

Two experimental studies investigated recognising and responding to social-affective stimuli (table 1). One study investigated children's abilities to label emotions using the child faces subtest of the Diagnostic Assessment of Non-verbal Accuracy test (DANVA-2; Tlustos et al., 2011). The results showed that children with a TBI were significantly worse at labelling facial expressions compared to the orthopaedic injury group (OI) group 18 months post injury (Tlustos et al., 2011). Tlustos et al. (2011) concluded that the emotional labelling skills of children with a TBI improved at a slower rate compared to children with OI.

Ryan et al. (2013) investigated children's ability to recognise facial and vocal emotions. Although the TBI sample size was small, the results of this study indicated that the brain injured group were more impaired at recognising facial and vocal emotions. Furthermore, Ryan et al.'s (2013) findings suggested that social communication (e.g. conversational turn taking; conversational distance; ability to adjust language to meet changing social constraints) mediates the association between poor emotion perception and more frequent externalising behaviours.

Despite a mean age difference between Tlustos et al.'s (2011), and Ryan et al.'s (2013) studies (3-6 years, 17-24 years respectively), the pattern of results suggest that children and adolescents with a TBI are significantly worse at facial and vocal emotion labelling. Furthermore, a deficit for recognising and responding to social-affective stimuli may worsen throughout development (Anderson et al., 2005; Tlustos et al., 2011) and may have an indirect effect on externalising behaviours (Ryan et al., 2013).

Table 1

Construct 2: Recognising and responding to social-affective stimuli studies

Study (author)	TBI group			Control group			Measures	Key Findings	Strengths	Limitations
	N	Age(s)	Age of injury	N	Age(s)	Description				
Ryan et al. (2013)	34	17-24 yrs	1 – 7 yrs	16	17-24	-	The Advanced Clinical Solutions Social Perception subtest (ACS; Pearson, 2009)	- The TBI group had significantly poorer emotion perception, social communication and greater externalising behaviours. - Social communication mediated the association between poorer emotion perception and more frequent externalising behaviours.	- Longitudinal (16 year follow up). - Used the Glasgow coma scale (GCS) as a brain injury measure of severity. - Model of mediation is clear.	- Small sample size (N=34). - Control group not matched in size (N =16).
Tlustos et al. (2011)	55	3-6 yrs	Mild TBI = 5.06 Moderate TBI = 5.03	82	3-6 yrs	OI	Child faces subtest of the DANVA-2	- Moderate-severe TBI group performance for labelling children's facial expressions was significantly worse than the OI group 18 months post injury. - The TBI group improved significantly slower compared to the OI group.	- 18 month follow up study. - Shows long term effects following TBI of emotional labelling. - Used the Glasgow coma scale as a brain injury measure of severity. - Shows the impact of moderate – severe brain injury.	- Lack of participant brain injury information. - Parental self-report used.

Note: OI = Orthopaedic injury
DANVA-2 = Diagnosis Assessment of Non Verbal Accuracy test

Construct 3: Low-level Mental State Inference

The third construct is low-level mental state inference and relates to vicariously living the experiences of others through internal biological and physiological feedback. Adolphs (2006) argued that accessing the sensory qualities of the observed expression, as if the expression was one's own, is critical in emotional recognition. This is made possible by the mirror neuron system (MNS), which enables the mimicking of other's expressions, emotions, intentions and actions (Pfeifer, Iacoboni, Mazziatta, & Dapretto, 2008).

There were no identified studies relating to low-level mental state inference. However, research in this area could be relevant. For example, studies have found that if people are prevented from mimicry, their ability to detect changes in emotional expression diminishes (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001). Moreover, de Sousa et al.'s (2010) study demonstrated that adults with a TBI were worse at spontaneously mimicking facial expressions. Further investigation into the facial mimicry abilities of children, adolescents and young adults with a TBI may contribute to the understanding of the mechanisms underlying socio-emotional processing for this population.

Construct 4: High-level State/Trait Inference

Ochsner's (2008) socio-emotional processing stream describes construct four as high-level state/trait inference. This is the ability to make a judgement on the meaning of socially ambiguous information with consideration of the wider context (Oldershaw et al., 2011). The processes involved include Theory of Mind (ToM) and inferring another's thoughts, beliefs or intentions. ToM studies have predominantly investigated first and second order ToM, whereby first order ToM is the ability to understand false beliefs and take the perspectives of others, and second order ToM is the ability to make inferences about a belief (Liddle & Nettle, 2006). Neuro-imaging studies implicate the superior temporal sulcus in ToM processing, along with the dorsal medial prefrontal cortex, inferior parietal cortex and anterior cingulate cortex (Gallagher & Frith, 2003).

Eleven experimental studies were identified for construct four (table 2). Eight studies investigated ToM for children and adolescents with TBI (Dennis et al., 2009; Dennis et al., 2012; Dennis et al., 2013a, Dennis et al., 2013b; Dennis et al., 2013c; Stronach & Turkrta, 2008; Turkstra, McDonald, & DePompei, 2001; Turkstra, Dixon, & Baker, 2004), one study explored trait attribution for adolescents and young adults with TBI (Newsome et al. 2010) and two studies investigated ToM for children under seven years old with a TBI. Stronach & Turkstra's (2008) and Turkstra et al.'s (2001; 2004) studies suggested that adolescents and young adults with TBI are significantly poorer in their ability to make mental state inferences and indicated impaired first and second order ToM. These findings are supported by a number of studies by Dennis and colleagues (2009; 2012; 2013a; 2013b; 2013c), which demonstrated impaired cognitive[4], affective[5] and conative[6] ToM for children and adolescents with TBI on a range of speech, pictorial scenario and facial emotion tasks.

Newsome et al. (2010) explored trait attribution abilities for adolescents with TBI using a trait attribution task. The study found that adolescents with TBI demonstrate impairments in self-awareness and in taking the perspectives of others (Newsome et al., 2010). In addition, adolescents with

[4] Cognitive ToM: Understanding another's cognitive beliefs (Dennis et al., 2013).
[5] Affective ToM: Understanding what someone feels or wishes to appear to feel (Dennis et al., 2013).
[6] Conative ToM: Understanding how to exert influence on what someone else feels (Dennis et al., 2013).

TBI showed greater activation in posterior brain regions implicated in social cognition (left lingual gyrus; posterior cingulate), with neural activity extending to neighbouring regions not typically associated with social cognition (Newsome et al., 2010). This suggests that adolescents with TBI use alternative neural pathways for social cognition resulting in poor performance.

Two studies by Walz et al. (2009; 2010) indicated that children with TBI experience deficits in first and second order ToM tasks compared to their peers. Furthermore, the results suggested that children who sustain a TBI earlier in childhood are more susceptible to ToM deficits (Walz et al. 2009; Walz et al. 2010).

The results of the eleven studies identified for construct four indicate that children, adolescents and young adults with TBI experience deficits in first and second order ToM, cognitive, affective and conative ToM and trait attribution. In addition, research suggests that adolescents with TBI may use alternative neural pathways for social cognition as a result of their injury (Newsome et al, 2010). However, the studies discussed in this review used a variety of different ToM measurement tools that differed in their sensitivity to ToM processes. Due to these inconsistencies, it is difficult to make collective conclusions from the results of the papers.

Table 2

Construct 4: High-level state/trait inference studies

Study (author)	TBI group			Control group			Measures	Key Findings	Strengths	Limitations
	N	Age(s)	Age of injury	N	Age(s)	Description				
Dennis et al. (2009)	43	7-16yrs	0 – 6 + yrs	-	-	-	Speech act measure of ToM	- TBI group performed significantly below normative data on the speech act measure of ToM. - Frontal injury impacted working memory, which impacted ToM.	- Area of brain injury categorised and assessed. - Developed models clear and applicable.	- Speech act task has not been tested against other ToM tasks. - Frontal injury locations not specified.
Dennis et al. (2012)	56	8-13yrs	After 3 yrs old	61	8-13yrs	OI	Jack and Jill Task (Dennis et al., 2012)	- TBI group performed significantly worse on the ToM task. - Children with severe TBI showed the lowest accuracy rates.	- Large TBI sample size. - Task able to be performed by both groups.	- Novel ToM task. - Only tested cognitive component of ToM.
Dennis et al. (2013a)	78	8-12yrs	Mild= 8.06 Moderate = 7.63	56	8-12yrs	OI	Emotional and Emotive Faces Task (EEFT) (Dennis et al., 2013a)	- TBI group performed significantly worse on the EEFT task compared to the OI group, indicating poorer emotive communication and emotional expression understanding.	- Large TBI sample size. - Other cognitive domains tested. - Used GCS.	- EEFT has cartoon static emotions. - Limited power.
Dennis et al. (2013b)	82	8-13yrs	12 – 63 months	61	8-13yrs	OI	Emotional and Emotive Faces Task (EEFT), The Jack and Jill Task, The Ironic Criticism and Empathic praise task (Dennis et al., 2001)	- Children with TBI have difficulty in cognitive, affective, and conative ToM. - Lesions in the Mirror Neuron Empathy network predicted lower conative ToM - Individuals with severe TBI experienced difficulties in cognitive ToM. - TBI experienced difficulties in affective and cognitive ToM.	- Large TBI sample size. - Separation of ToM processes. - Used GCS as a brain injury measure of severity.	- Did not obtain good quality data for all MRI scans.
Dennis et al. (2013c)	71	8-13yrs	*M* = 10 yrs	57	8-13yrs	OI	The Ironic Criticism and Empathic praise task	- TBI group were worse for indirect speech acts involving conation (e.g. irony and empathy). - Deficits were more widespread and greatest for individuals with severe TBI.	- Large TBI sample size. - Match control group. - Used GCS.	- Lab setting. - Other forms of empathy (e.g. altruism) not measured.
Newsome et al. (2010)	9	12-19yrs	9.36-17.03 yrs	9	12-19yrs	TD	Trait attribution task	- Adolescents with moderate to severe TBI use alternative neural pathways during perspective-taking because of	- Used GCS. - Heterogeneous sample.	- Small sample size. - Group IQ not

								damage to their fronto-parietal networks that mediate social cognition. - When thinking of the self from a third-person perspective, adolescents with TBI demonstrated greater neural activation for areas associated with social cognition and activation in neighbouring regions,	- Distinct neurological findings.	matched. - MRI is a false environment (e.g.lab setting).
Stronach & Turkstra (2008)	16	17.5yrs	3.6 - 20.1yrs	8	17.2yrs	TD	Video stimuli social cognition test for adolescents, Videotaped conversations analysed using SALT	- TBI group had they differed significantly in impairments in ToM. - TBI group expressed significantly fewer cognitive state terms and significantly fewer self- vs other-referenced terms than either the TD group, indicating ToM deficits.	- Computerised analysis of transcripts. - Good transcript inter-rater agreement	- Small sample size. - Group numbers not matched. - Participant chose their topic on the conversation task – so it is uncontrolled.
Turkstra et al. (2001)	10	13-21yrs	-	60	13-21	TD	Video stimuli social cognition test for adolescents	- TBI group differed significantly for impairments in ToM. - TBI group were worse at making mental state inferences, especially related to the detection of sarcasm and bragging.	- Novel real life situation task. - Task reliability and validity considered.	- Group numbers not matched. - Lab setting.
Turkstra et al (2004)	22	13-21	-	48	13-21	TD	Video stimuli social cognition test for adolescents	- TBI adolescent scored significantly lower for social cognition tasks requiring second order ToM.	- Social and cultural beliefs considered in analysis.	- Self report social knowledge and beliefs measures used – no significant results.
Walz et al. (2009)	59	3-5yrs	3 yrs to 5yrs 11m	86	3-5yrs	OI	ToM battery consisting of appearance-reality tasks, false contents tasks, false location tasks, and control tasks	- Children who sustain TBI in early childhood are susceptible to deficits in first-order ToM skills, but that these deficits are likely to be subtle and dependent on a child’s age and overall cognitive functioning.	- Age and IQ considered and were predictors. - Large test battery administered.	- Lack of TBI information (e.g. length of PTA). - Small server TBI sample size.
Walz et al. (2010)	42	*M* =6.98 yrs	5-7yrs	52	5-7yrs	OI	ToM battery consisting of appearance-reality tasks, false contents tasks,	- Children with severe TBI had poorer ToM performance than children with orthopaedic injuries. - Children with severe TBI did not engage in representation of first- and second-	- 1 year post injury allowed time for neurological recovery following TBI.	- Small sample size, especially for severe TBI group. - Group numbers

			false location tasks, and control tasks	order mental states at a developmental level comparable to their peers.	- Verbal abilities and age accounted for and found to be predictors of ToM.	not matched.

Note: OI = Orthopaedic injury; TD = Typically developing; SALT = Systematic Analysis of Language Transcripts.

Construct 5: Context-Sensitive Regulation

Context-sensitive regulation refers to the ability to regulate judgements, behaviours and emotions in response to receiving social information (Oldershaw et al., 2011). These processes of context-sensitive regulation rely on the prefrontal cortex (Ochsner, 2008).

Eight studies investigating childhood and/or adolescent TBI and context-sensitive regulation were identified (table 3). Ganesalingam et al. (2006; 2007a; 2007b) reported that children with a TBI experienced deficits in self-regulation which accounted for social and behavioural functioning difficulties, poorer social problem solving and a greater frequency of aggressive behaviours. Ganesalingam et al. (2007a) suggested that emotional self-regulation may be a core deficit in children who display social and behavioural difficulties after TBI.

Using the social-moral reasoning aptitude test (So-moral: Dooley, Beauchamp, & Anderson 2010) and the So-mature task (Dooley et al., 2010), Beauchamp, Dooley and Anderson's (2013) study identified that adolescents with a TBI had significantly poorer moral reasoning and lower empathy compared to controls in social situations. Beauchamp et al. (2013) concluded that the deficit in moral reasoning experienced by adolescents with TBI may place them at risk of poor social decision making and socially unacceptable behaviour.

To investigate context-sensitive responses and regulation, Turkstra et al. (2008) used the Cognitive Assessment of Spoken Language (CASL) Pragmatic Judgement Test (Carrow-Woodfolk, 1999). The results indicated that adolescents with TBI were significantly less able to generate context-appropriate responses (Turkstra et al., 2008). In addition, Leblanc et al.

(2005) identified that younger TBI patients exhibited greater response inhibition recovery.

Two studies employed a child modified version of the Iowa Gambling Task (IGT) (Bechara, Damasio, Damasio, & Anderson, 1994) to investigate choice-based and outcome-based regulation (Hanten et al., 2006; Schmidt et al., 2011). Although the modified IGT task did not have reliability data to support the outcomes, the results of the studies indicated that children with TBI have impaired decision making (Hanten et al. 2006) and that outcomes are effected by age and gender (performance gradually improves overtime; females are more risk averse; Schmidt et al., 2005). In addition, Hanten et al. (2006) demonstrated that children with amygdala lesions were impaired on the IGT, whereas children with ventromedial lesions did not appear to be impaired, indicating that location of injury is an important factor on performance.

The results of the studies suggest that children and adolescents with a TBI may have impairments in regulating their behaviour, decision making and generating context-sensitive responses. These subtle difficulties may make it harder to negotiate the complexities of social relationships and to develop their social skills (Turkstra et al., 2008).

Table 3

Construct 5: Context-sensitive regulation studies

Study (author)	TBI group			Control group			Measures	Key Findings	Strengths	Limitations
	N	Age(s)	Age of injury	N	Age(s)	Description				
Beauchamp et al. (2013)	25	Mean age = 13.34	Mild TBI = 12.08 yrs Moderate = 12.92 yrs	66	Mean age = 13.95	TD	Socio-Moral Reasoning Aptitude Level (So-Moral), So-Mature Task	- The TBI group had lower levels of moral reasoning and empathy. - Empathy correlated positively with moral reasoning.	- Age and IQ considered and used as covariates.	- Small sample size, especially for severe TBI group. - Empathy measure did not capture cognitive or affective empathy individually.
Ganesalingam et al. (2006)	65	6-11yrs	*M* = 8.02 yrs	65	6-11yrs	TD	TEA-ch, MFFT, ERC, DGT	- Children with TBI displayed deficits in self-regulation and social and behavioural functioning. - Self-regulation accounted for significant variance in children's social and behavioural functioning. - Emotional self-regulation may be a core deficit in children who display social and behavioural difficulties after TBI.	- Large battery of standardised tests used. - Large sample size. - Follow up study – 3-5 yrs after injury (shows long term effects).	- Groups obtained from different countries (TBI = Australia, Control = New Zealand). - IQ not assessed. - Parental and teacher self-report used.
Ganesalingamet al. (2007a)	65	6-11yrs	*M* = 8.02 yrs	65	6-11yrs	TD	TEA-ch, MFFT, ERC, DGT	- Self-regulation accounted for individual variation in the outcomes. - Self-regulation acted as a significant mediator of the effects of TBI on the outcomes. - Self-regulatory deficits may account for post-injury difficulties in social and behavioural functioning.	- Built on results of previous study. - Large battery of standardised tests used. - Large sample size. - Mediation models consistent with developmental studies.	- Groups obtained from different countries (TBI = Australia, Control = New Zealand). - IQ not assessed. - Parental and teacher self-report used. - Language ability not controlled for.
Ganesalingamet al.	65	6-11yrs	*M* = 8.02	65	6-11yrs	TD	TEA-ch, MFFT, ERC, DGT	- Self-regulatory skills accounted for significant variance in their solutions to	- Built on results of previous study,	- Groups obtained from different

(2007b)			yrs					social problems. - Better self-regulation predicted more assertive solutions and fewer aggressive solutions.	-Large battery of standardised tests used. -Newly developed task identified aggressive solution taking,	countries (TBI = Australia, Control = New Zealand). - IQ not assessed. - Language ability not controlled for. - Newly developed task used.
Turkstra, e t al. (2008)	9	13-21yrs	6– 20 yrs	9	13-21yrs	TD	CASL Pragmatic Judgment test	- Adolescents with TBI were significantly less able than their peers to generate context-appropriate responses in everyday pragmatic situations.	- Age and sex matched control group. - Use of standardised tests. - Clinical implications discussed and clear.	- Small sample size. - Heterogeneous and small recruitment area.
Hanten et al. (2006)	11	8-16yrs	6– 14 yrs	-	-	-	IGT modified for children	- Children with lesions in the amygdala were impaired on the IGT, indicating poorer decision making. - Children with ventromedial lesions did not appear to be impaired on the task. -	-Use of standardised tests, - Comparison of different brain areas.	-Small sample size. -IGT modified for the study' - Reliability of brain area isolation for the results.
Leblanc et al. (2005)	136	5-16yrs	0 – 2yrs post injury	117	5-16yrs	TD	Stop-signal task	- Younger TBI patients were initially more impaired although they exhibited greater recovery of response inhibition than did older TBI patients. - Longer duration of coma predicted initial deficits. -	-Repeated measurement taken at set times. -Longitudinal data. -Large age matched control group.	-Dependent on motor abilities (motor response). -Other cognitive variables not accounted for.
Schmidt et al. (2011)	135	*M = 13.38*	*M = 13.38*	64	7-17 yrs	OI	IGT modified for children	- Children with a TBI show impairments in decision making. - The nature of the effects is influenced by both age and gender.	-Large sample size. - Multiple assessments at set times points (3,6,12 months etc.).	- IGT modified for the study. - Not all participants assessed at each time point.

Note: OI = Orthopaedic injury; TD = Typically developing; TEA-ch = Test of every day attention of children; MFFT = Matching familiar figures; ERC = Emotion regulation checklist; DGT = Daily gratification task; IGT = Iowa Gambling Task; INS = Interpersonal negotiation strategy task

Discussion

General Summary

This review identified 21 studies using experimental paradigms to investigate socio-emotional processing for children, adolescents and young adults with TBI. The studies were grouped and reported according to the five constructs of Ochsner's (2008) socio-emotional processing model.

Broadly, the findings indicate that children, adolescents and young adults with TBI experience difficulties in facial emotion processing, theory of mind and response recognition. These difficulties can be mapped onto constructs two, four and five of Ochsner's (2008) model. No studies investigating constructs one (social affective response) or three (low level mental state inference) were identified.

The studies identified in this review, highlighted that children and adolescents with TBI experienced deficits in facial and vocal emotion labelling (construct two: recognising and responding to social-affective stimuli). Evidence suggests that these deficits may become more profound throughout development as social affective stimuli becomes more complicated and requires a higher level of processing (Anderson et al., 2005; Tlustos et al., 2011).

Studies relating to construct four indicated that individuals with TBI experience deficits in trait attribution, making mental state inferences, and for first and second order ToM. Evidence relating to context sensitive regulation (construct five) indicted that children and adolescents with TBI experience difficulties in: regulating their behaviour; appropriate decision making; understanding the pragmatics of social communication and functioning; responding appropriately within the context of the situation. In addition, the research suggests that poor emotional self-regulation is associated with social and behavioural difficulties after TBI.

Ochsner's (2008) model proposes that each socio-emotional construct has distinct brain regions associated with it. This review identified only two studies using imaging to investigate the neural activation (Hanten et al. 2008; Newsome et al. 2010). Newsome et al.'s (2010) study investigated trait attribution (construct 4) and reported that adolescents with TBI use alternative neural pathways for social cognition with greater activation in posterior brain regions and neighbouring regions not typically associated with social cognition. Hanten et al.'s (2008) context sensitive regulation (construct 5) study demonstrated that children with lesions in the amygdala were impaired on the IGT, whereas children with ventromedial lesions showed no impairment. The results suggest that the location of injury is an important performance factor. Newsome et al. (2010) and Hanten et al. (2008) identified specific neural regions for two socio-emotional processes that are consistent with constructs four and five of Ochsner's (2008) model and provide some support for the distinct neurological processes proposed by Ochsner (2008). However, Ochsner's (2008) model has a limited research base and further experimental and neuroimaging research would be required to examine the construct-neural associations described in the model.

The results of the literature review indicate that for the childhood, adolescent and young adulthood TBI population, there is only limited evidence to support the emotional processing stream proposed in Ochsner's (2008) model. Studies identified could only be found in relation to three of the five constructs of the model (construct 2: emotion recognition; construct 4: high-level mental state inference; construct 5: response inhibition). The identified studies could not be mapped onto constructs one or three of the model (social affective values and responses and low-level mental state inference, respectively). Consequently, this review does not provide support for the model and it may not be suitable for this TBI population.

The identification and development of suitable socio-emotional processing models for this population would appear to be important, given that the population appears to experience deficits in this area, which are associated with poorer outcomes later in life (e.g. a greater frequency of externalised inappropriate responses (Ryan et al., 2013)). Such models may offer means to identify gaps in the TBI socio-emotional literature, and develop testable hypotheses. Furthermore, a suitable model may provide guidance to assessment and treatment processes for TBI related socio-emotional difficulties. It is possible that other models of socio-emotional processing (e.g. Crick and Dodge, 1994, Lemerise and Arsenio, 2000; Tonks et al, 2009) could give a more complete account of the socio-emotional deficits identified within the TBI population and are therefore more suitable for integrating the current research. Future research could seek to examine the appropriateness of these models for this population.

Limitations

There are two clear limitations to this review. First, the search only included papers written in English, which primarily limited the search to western hemisphere publications. A search including papers written in other languages may have produced a more holistic representation of the research area.

Second, there are some methodological limitations within the studies identified. There was a large variation of experimental paradigms which makes it difficult to directly compare the results of the studies, thus limiting the conclusions that can be drawn from the findings. Moreover, the studies do not account for factors that may also effect socio-emotional processing, such as mood disorders or childhood neglect. The inclusion of co-morbid disorders would enable increased understanding of the impact of TBI with regards to socio-emotional processing difficulties.

Future Research and Clinical Implications

Future research could aim to increase the understanding of socio-emotional processing deficits in children, adolescents and young adults with TBI. Such research may be vital to drive the development of relevant models for socio-emotional processing. This would, in turn, offer the means to enhance the ability to know what to assess and how to develop relevant interventions. Further, research should be replicated using consistent experimental designs and consider the effects of co-morbid mental health problems on outcomes. In addition, it should ensure good sample numbers to avoid type two errors.

Future research could also aim to further its clinical impact through the development of emotional processing specific interventions where appropriate. For example, Baron-Cohen (2002) developed a ‘Mind Reading’ programme for individuals with ASD which has been shown to improve recognition across a range of different emotions.

Conclusions

This review has highlighted that children, adolescents and young adults with TBI experience a range of socio-emotional processing difficulties. It attempted to integrate the findings of the identified studies onto Ochsner’s (2008) socio-emotional functioning stream. The results suggest that, due to the lack of supporting evidence, with only three of the five constructs being applicable to the identified studies, Ochsner's (2008) model may not be suitable for enhancing our understanding of socio-emotional processing within this population. Future research should aim to examine the suitability of alternative models of socio-emotional processing for the childhood, adolescent and young adulthood TBI population. The identification of a suitable model for this population may allow the clear categorisation of difficulties and identify any gaps in the literature base.

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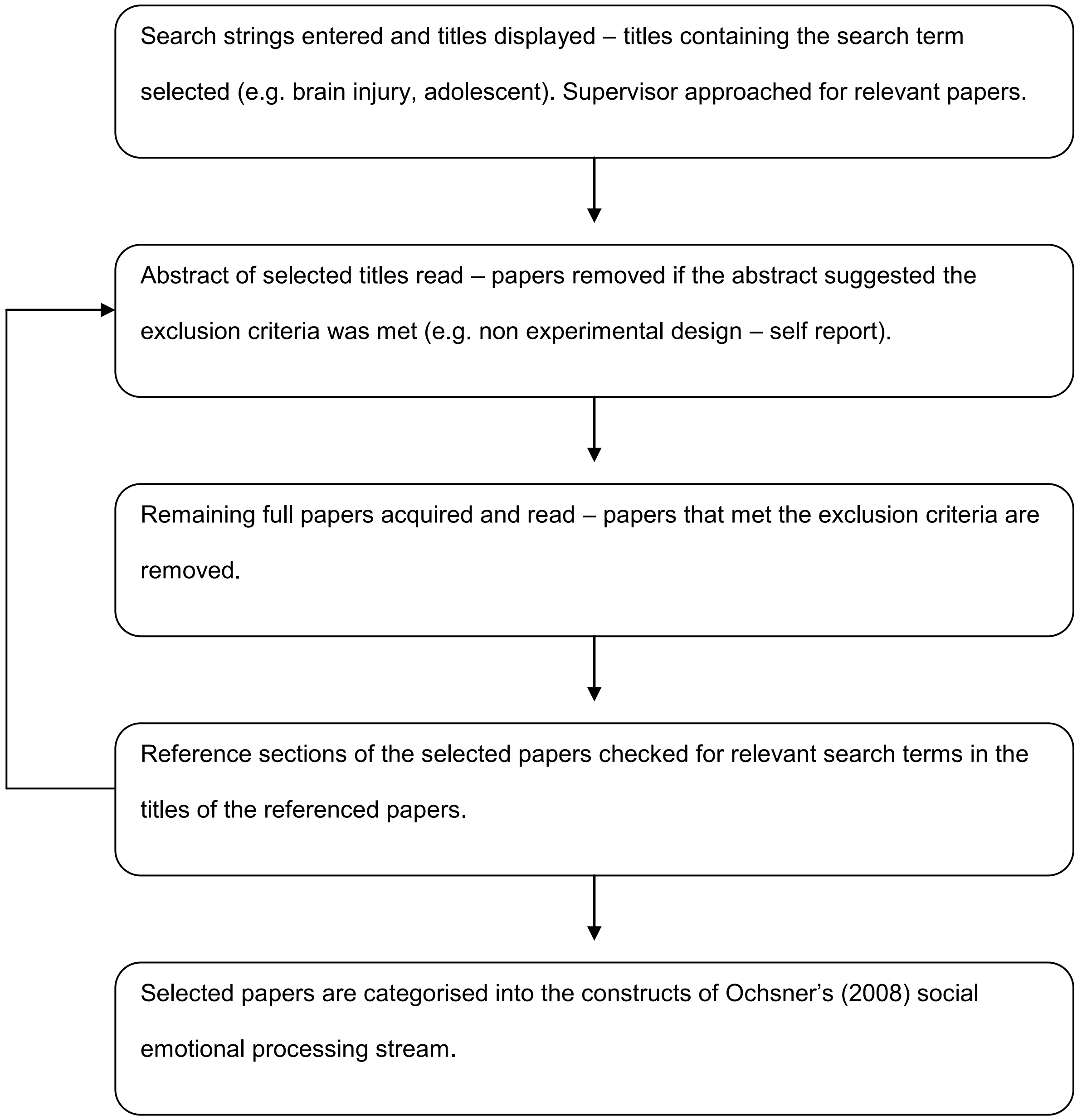
Appendix 1

A flow chart of the paper search strategy and selection



Empirical Paper: A Pilot Study on Socio-emotional Processing in Young Adult Offenders with Traumatic Brain Injury

Name: Mr Jac Rhys Dendle

Supervisors: Professor Huw Williams, Dr Anke Karl

Target Journal(s): Journal of Head Trauma Rehabilitation

Research Setting: Her Majesty's Prison Young Offenders Institute, A Youth Offending Team (YOT), A Targeted Youth Support (TYS) Services.

SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE DOCTORATE IN CLINICAL PSYCHOLOGY

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Abstract

Objective: Research has demonstrated deficits in socio-emotional processing following childhood traumatic brain injury (TBI; Tonks et al., 2009a). However, it is not known whether a link exists between socio-emotional processing, TBI and offending. Drawing on Ochsner's (2008) socio-emotional processing model, the current study aimed to investigate facial emotion recognition accuracy and bias in young offenders with TBI. ***Setting:*** Research was conducted across three youth offender services. ***Participants****:* Thirty seven participants completed the study. Thirteen participants reported a high dosage of TBI. ***Design:*** The study had a cross sectional within and between subjects design. ***Main Measures:*** Penton-Voak and Munafo's (2012) emotional recognition task was completed. ***Results:*** The results indicated that young offenders with a TBI were not significantly worse at facial emotion recognition compared to those with no TBI. Both groups showed a bias towards positive emotions. No between group differences were found for emotion bias. ***Conclusion:*** The findings did not support the use of Ochsner's (2008) socio-emotional processing model for this population. Due to the small sample size, inadequate power and lack of non-offender control groups, it is not possible to draw any firm conclusions from the results of this study. Future research should aim to investigate whether there are any links between TBI, socio-emotional processing and offending.

Keywords: Traumatic Brain Injury, Offending, Socio-emotional Processing, Facial Emotion Recognition

Introduction

Offending and reoffending rates are high in adolescents and young adults (Forrest, Tambor, Riley, Ensminger, & Starfield, 2000), with the 88,000+ England and Wales prison population consisting of 866 juveniles (15-17 years of age) and 19,094 young adults (18-24 years of age) in 2013 (Berman, & Dar, 2013). Male gender, urban dwelling and lower socio-economic status (SES) have been shown to be risk factors for both crime (Eisner, 2003) and traumatic brain injury (TBI) (Yates et al., 2006). TBI prevalence rates of all severities have been reported as higher than the normal population in juvenile and young adult prison populations: 5%-24% and 18%-65% respectively (McGuire,Burright, Williams & Donovick, 1998; Perron & Howard, 2008; Williams, Giray, Mewse, Tonks, & Burgess, 2010). In a study of young offenders by Williams et al. (2010), 46% reported a TBI with a loss of consciousness (LOC), 29.6% a mild traumatic brain injury (mTBI)[1] and 16.6% a moderate to severe TBI[2]. In addition, Williams et al. (2010) found that repeated injury was common for adolescent offenders, with 32% having more than one episode of a loss of consciousness (LOC). The elevated rates of TBI in the young adolescent and young adult offender population suggest that it is a potentially important, yet neglected phenomenon, within the custodial system.

Consequences of TBI

Moderate to severe TBI is typically associated with neuropsychological deficits, psychosocial difficulties and behavioural problems (Croker & McDonald, 2005). For example, Meythaler, Pedizzi, Eleftherious and Novack (2001) indicated that following a TBI an individual may experience global cognitive deficits, impaired memory and reduced processing. In addition, Max, Robertson and Lansing (2001) suggested that following severe TBI, individuals can experience personality change

[1] Loss of consciousness (LOC) for less than 10 minutes.
[2] LOC of ten minutes to six hours, or more.

with the most common being emotionally labile and aggressive/disinhibited subtypes. Mild traumatic brain injury (mTBI) is associated to a lesser extent with such persisting problems. However, neuropsychological sequelae (e.g. deficits in memory, attention, executive function, information processing, verbal fluency) can occur for complicated or cumulative injuries (Iverson, 2006; Williams, Potter, & Ryland, 2010; Williams, Levin, & Eisenberg, 1990).

Davies, Williams, Hinder, Burgess and Mounce (2012) reported that post concussion symptoms increased with frequency and severity of TBI. Furthermore, Teasdale and Engberg (2003) reported that repeated head injuries were associated with greater cognitive dysfunction compared to a single injury for adolescents under the age of 18. In line with this, multiple mTBIs have been associated with worse performance on complex attention and executive function tasks (Collins, Grindel, & Lovell, 1999; Wall et al., 2006). Wall et al. (2006) suggested that suffering an injury at a younger age, and repeated injury within a short time span, are important factors for increased neuropsychological deficits. In support of this, research has indicated that the neurological stress incurred following a TBI can increase the potential vulnerability to subsequent injury and greater deficits (Echemendia & Julian, 2001). In summary, the literature indicates that severity, frequency and age at injury, are key components in predicting neuropsychological deficits following a TBI.

TBI and Offending

Strong links between TBI and offending behaviour has been evidenced by longitudinal research from Scandinavia. For example, Timonen et al. (2002) indicated that suffering TBI in childhood or adolescence increases fourfold the risk of developing a mental disorder and offending later in life. TBI has been shown to be a moderate risk factor for committing a violent crime when compared to the general population and sibling controls (Fazel, Lichtenstein, Grann, & Långström, 2011).

Furthermore, those with focal TBI injuries showed higher rates of violent crime compared to those with haemorrhage related injuries. Similar to the patterns found in the TBI and cognitive deficits research, it would appear that severity and age are important factors in the relationship between TBI and crime. Individuals with concussion only, or a first diagnosis of TBI over 16 years of age, demonstrated lower rates of violent crime (Fazel et al., 2011). Leon-Carrion and Ramos (2003) also reported that a history of un-treated TBI in childhood or adolescence was associated with sentencing for violent offending in adults. Although the literature base is small, there is developing evidence that a TBI in childhood or adolescence may increase the risk of offending later in life.

With regards to TBI frequency, Williams et al. (2010) indicated that within a youth offending population, frequency of self-reported TBI was associated with more convictions. Furthermore, three or more self-reported TBIs was associated with greater violence in offences (Williams et al., 2010). However, these results are based on self-reported head injury and not medical records. Consequently, head injury may be reported inaccurately, which could affect the reliability of the study's results.

TBI and offending populations both exhibit socially inappropriate and disinhibited behaviours (Williams, et al., 2010; Williams, Papadopoulou, & Booth, 2012). There are a number of shared cognitive and socio-environmental characteristics that may contribute to these behaviours. For example, low socio-economic status and family environments have been shown to be risk factors for both TBI and crime (Kenny & Lennings, 2007; Raine, Brennen, & Farrington, 1997). Furthermore, communication related difficulties are prevalent in both populations (Chitsabesan, et al., 2007; Hughes, Williams, Chitsabesan, Davies, & Mounce, 2012; Williams et al., 1990). Bryan et al. (2007) found elevated rates of developmental difficulties for "speaking grammar" and "listening vocabulary" within the young offender population. Similarly, expressive and receptive vocabulary difficulties are well documented in the brain injury literature (e.g. Catroppa, & Anderson, 2004; Savage, DePompeo, Tyler, & Lash, 2009). Deficits in language ability have been associated with behavioural problems and delinquency (Beitchman et al., 2001; Brownlie et al., 2004). The environmental and cognitive similarities between TBI and offender groups make it difficult to disentangle the processes that could be contributing to offending behaviour and determine whether a relationship exists between TBI and crime.

Despite research providing evidence for elevated TBI rates in young offenders compared to non-offenders (Perron & Howard, 2008; Williams et al., 2010) and the identification of some shared characteristics, there is still relatively little known about the neuropsychological consequences of brain injury and whether there is any association with offending behaviour. Consequently, the potentially detrimental effects of TBI (e.g. neuropsychological deficits, behavioural and psychosocial problems) may not be fully appreciated within the youth justice system (Williams et al., 2010).

TBI and Socio-Emotional Processing

Socio-emotional processing is important for appropriate social functioning. Individuals with poor socio-emotional processing exhibit a higher frequency of externalising behaviours, resulting in inappropriate responses and social misunderstandings (Ryan et al., 2013). Socio-emotional processing requires a number of complex cognitive processes associated with several neural structures (Johnson et al., 2005). The prefrontal cortex, anterior cingulate, amygdala, insular, and temporal areas of the brain, have all been associated with verbal and socio-emotional processes (Beason-Held, Goldski, Kraut, Esposito, & Resnick, 2005;

Ochsner, 2008). Research has also indicated that the amygdala, hippocampus, orbitofrontal, temporal, parietal and occipital cortices are involved in both visuo-spatial and socio-emotional processes (Haxby, et al., 1991; Tonks et al., 2008). Damage sustained during brain injury can potentially prevent the normal development of the neurological pathways and systems required for socio-emotional processing (Anderson Catroppa, Morse, Haritou, & Rosenfeld, 2005; Tonks et al., 2009a). As social situations become more demanding throughout adolescence and young adulthood, an individual who has suffered a childhood TBI may not have developed the required social and cognitive skills to cope with such demands (e.g. complex social rules, a widening social network, a variation of rules based on environment; Tonks et al., 2009a). Case studies suggest that socio-emotional deficits are particularly prominent when brain injury has occurred during childhood and remains persistent throughout development (Eslinger, Flaherty-Craig, & Benton, 2004).

Within the developmental and neurodisability literature a number of models have been developed for socio-emotional processing. For example, based on the child social information and adjustment literature, Crick and Dodge (1994) developed the social information processing (SIP) model involving five distinct cognitive stages that occur in response to a social situation (encoding, representation, response searching, selecting a response, acting). However, social interaction is not just a cognitive process (Ochsner, 2008) and, subsequently, Lemerise and Arsenio (2000) revised the SIP model (Crick & Dodge, 1994) to include emotion processing. Tonks et al. (2009a) proposed a three stage developmental model of emotion recognition for children and described the potential detrimental effects of childhood TBI within the model. The first stage of Tonks et al.'s (2009a) model is a fast unconscious recognition response that relies on subcortical brain structures (developed from birth). The second is a conscious process of emotion recognition involving more sophisticated cortical subsystems (developed at approximately 18 months old), and the third requires the synthesis of emotion and cognition to guide thought and response (developed throughout childhood). Although the models described above share common themes, none of them combine the categorisation of cognitive and emotional processes with neurological processes. For example, Lemerise and Arsenio's (2000) model does not consider cortical structures and Tonks et al.'s (2009a) model describes the critical phases in childhood social emotional development, including neurological development, but does not break down or categorise the processes involved. Furthermore, Tonks et al.'s (2009a) model is speculative and based on a review of the research to that date. The model has never been explicitly tested.

Synthesising concepts described in papers by Crick and Dodge (1994), Lemerise and Arsenio (2000) and Tonks et al. (2009a), Ochsner's (2008) socio-emotional processing stream incorporates both affective/unconscious and cognitive/conscious processes and considers the cortical structures involved. Ochsner (2008) used the emerging animal and human neural literature and theoretical models of social cognition and emotion to construct a framework. The five constructs of the socio-emotional processing stream are distinct in cognitive process and neural systems (figure 1; Ochsner 2008). According to Ochsner's (2008) model, the constructs lie along a hierarchy of processes in which we undertake the following: learn the value of a stimulus (construct 1); re-encounter it and recognise its value (construct 2); understand the beliefs and feelings of a stimulus (including oneself) in a bottom-up, experiential (construct 3) or top-down, attributional manner (construct 4); attempt to regulate responses to a stimulus in a context appropriate manner (construct 5).

Ochsner's (2008) review identified a number of neural structures and systems involved in socio-emotional processing at each construct level. For example, the review indicated that construct one involves amygdala and striatum neural activation; construct two requires input from the amygdala, insula, temporal sulcus, temporal parietal junction and ventromedial prefrontal cortex; construct three activates the mirror neuron system (MNS). In addition, Ochsner's (2008) review implicated the superior temporal sulcus, dorsal medial prefrontal cortex, inferior parietal cortex and anterior cingulate cortex for construct four and indentified that construct five requires prefrontal cortex input.

Although the evidence base is limited, Ochsner's (2008) socio-emotional processing stream appears to create a platform to consider cognitive, emotional and neurological processes together. These are important processes to consider following brain injury and make it a potentially appropriate model for TBI. The model provides the opportunity to identify and isolate specific socio-emotional processes. It could therefore facilitate the targeting of specific behaviours and emotional processes that may require intervention. Furthermore, the model's synthesis of the cognitive, emotional and neurological processes may allow the formulation of a heuristic that could enable the identification of gaps in the TBI socio-emotional literature and develop testable hypotheses.

Ochsner's (2008) socio-emotional processing stream is untested for TBI populations. However, experimental research can be mapped onto the constructs of the model. Research has indicated that impulsive aggressive patients with an acquired brain injury (ABI) show a bias towards labelling neutral faces as fearful or disgusted and that aggressive offenders misattribute neutral faces as negative (construct 1; Best, Williams, Coccaro, 2002; Penton-Voak et al., 2013).
Furthermore, children and young adults with TBI have been shown to be worse at

labelling and recognising emotions (construct 2; Tlustos et al., 2011; Tonks et al., 2007; Tonks et al., 2008). More specifically and relating to construct two, adults with TBI have been shown to be worse at recognising negative facial emotions compared to recognising positive emotions (Babbage et al., 2011; Croker & McDonald, 2005; Green, Turner, & Thompson, 2004; Hopkins, Dywan, Segalowitz, 2002; Jackson & Moffat, 1987). Research has also suggested that if an individual is prevented from facial mimicry then their ability to detect emotional expression diminishes (construct 3; Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001).

In line with construct four, deficits have been evidenced within TBI populations for first and second order theory of mind (ToM)[3] and trait attribution (Dennis et al., 2009; Newsome et al., 2010; Stronach & Turkrta, 2008; Turkstra, McDonald, & DePompei, 2001; Turkstra, Dixon, & Baker, 2004; Walz et al. 2009; Walz et al. 2010). Individuals with TBI have also been shown to have impairments in regulating behaviour and decision making (construct 5; Ganesalingam et al., 2006; Ganesalingam et al., 2007a; Ganesalingam et al., 2007b; Hanten et al., 2006; Schmidt et al., 2011; Turkstra et al., 2008). It is arguable that deficits in any of the five constructs of Ochsner's (2008) model may have a detrimental impact on social functioning.

[3] First order ToM is the ability to understand false beliefs and take the perspectives of others. Second order ToM is the ability to make inferences about a belief (Liddle & Nettle, 2006).

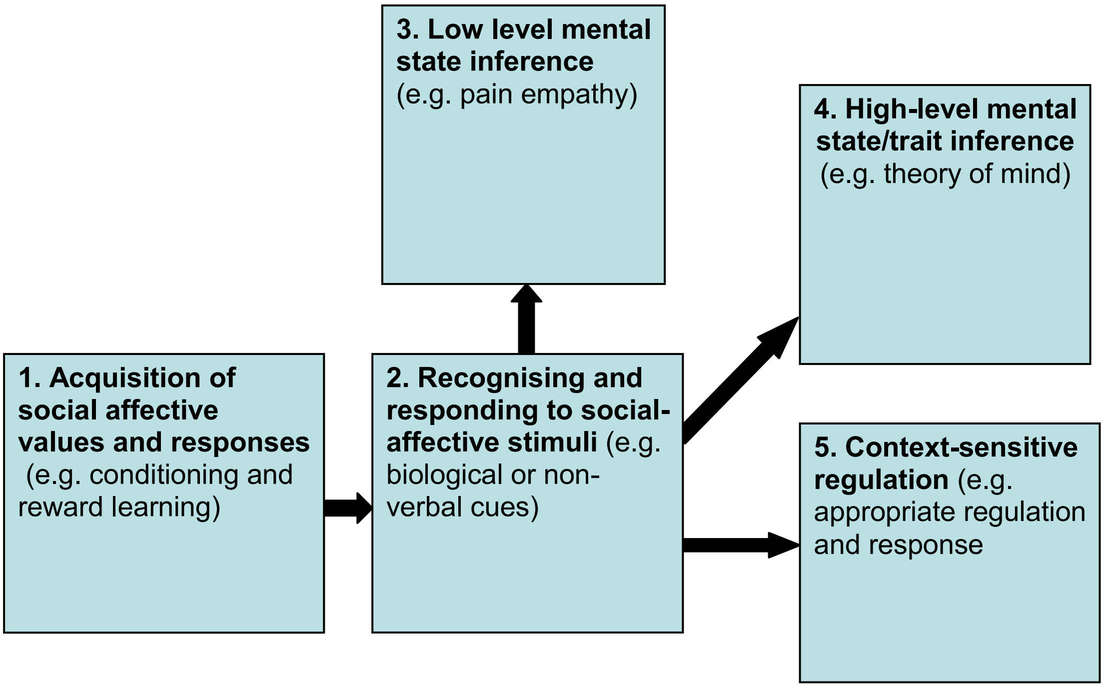

Figure 1: The five constructs of the socio-emotional processing stream (adapted from Ochsner, 2008).

The Current Study

Although there has been research that has begun to explore childhood and young adult brain injury and socio-emotional processing difficulties, there are relatively few studies investigating socio-emotional processing deficits for young adult offenders with TBI. The identification of offenders with TBI and any associated deficits could guide the development of appropriate interventions and may reduce the risk of future offending. Moreover, the developmental and social shifts during adolescence and young adulthood may make it a critical period of life for diverting young offenders into non-offending lifestyles (Williams et al., 2010). The categorisation of socio-emotional deficits experienced by young adult offenders with TBI into an existing model could be used to develop emotional recognition training and direct the improvement of the services.

For the purposes of this study, Ochsner's (2008) framework of socio-emotional processing was used in order to gain an oversight into the complex cognitive, emotional and neurological processes involved in socio-emotional processing. Although it remains untested within TBI populations, the model was chosen due to its synthesis of cognitive, emotional and neurological processes into five distinct constructs and its potential to develop testable hypotheses from each of these constructs. Ochsner's (2008) framework allows for the conceptualisation of two key issues that may relate to aggression after TBI. First, TBI may lead to impairment in labelling and recognising emotions (Tlustos et al., 2011; Tonks et al., 2007; Tonks et al., 2008). It is therefore predicted that those with a TBI will be worse at labelling and recognising emotions. Consequently, these individuals may fail to understand the emotions of others and may respond inappropriately. Second, given that following TBI individuals can have problems with aggressive personality changes (Max et al., 2001), and aggression is linked to the misattribution of emotion (Crick & Dodge, 1996), then it may also be that those with TBI misperceive neutral situations and expressions as negative. This is supported by Best et al.'s (2002) study in which they found aggressive patients with an ABI in the orbital/medial prefrontal cortex were biased towards labelling neutral faces as negative (disgust and fear). Such impairments and misattributions may well contribute to the trend that self-reported TBIs are linked with greater violence in offences (Williams et al., 2010). This preliminary study aimed to investigate whether young adult offenders with TBI experienced socio-emotional difficulties within two socio-emotional constructs of Ochsner's (2008) model: facial conditional bias (construct 1); and face emotion recognition accuracy (construct 2). It was hypothesised that:

Hypothesis 1: Young offenders with a high dosage of TBI will be poorer at recognising/labelling facial emotions compared to offenders with no or low dosage of TBI.

Hypothesis 2: Young offenders with a high dosage of TBI will show a bias towards negative facial emotions compared to positive facial emotions.

Hypothesis 3: Young offenders with a high dosage of TBI will show a greater bias towards negative facial emotions compared to young offenders with no or low dosage of TBI.

Methods

Design

The research was a cross-sectional within and between group design comparing a high dosage TBI group with a no or low TBI dosage group. The TBI group was the primary independent variable (IV), and facial recognition accuracy and facial emotion bias were the primary dependent variables (DV). Based on the literature indicating that neuropsychological difficulties are more prominent following a moderate/severe TBI or multiple TBIs (Collins et al., 1999; Echemendia & Julian, 2001; Wall et al., 2006) and Williams et al.'s (2010) youth offending study reporting three or more self-reported TBIs were associated with greater violence in offences, participants were allocated to one of the following experimental groups: 1) a group containing offenders with a moderate-severe TBI and/or three of more TBIs – 'high dosage of TBI'; 2) a group containing offenders with no TBI and/or less than 3 mTBIs – 'no or low TBI'. For the remainder of this study group one will be referred to as the 'high dosage of TBI group' and group two the 'no or low TBI group'.

Participants

Participants (N = 37) consisted of service users from a community-based Young Offenders Team (YOT) and a Targeted Youth Support service (TYS) in the south west of England and prisoners currently detained in a Her Majesty's Prison Young Offenders Institute (HMP/YOI) in London. The study age range was based on the World Health Organization age bands for adolescents (10-19 years of age) and young adults (20-25 years of age). The inclusion criteria were met by all the participants (appendix 3). From the YOT and TYS services a total of 27 young people were recruited (72.79% of the sample population), eighteen male and nine female, ranging from 14 and 19 years of age (*M*= 16.30, *SD* = 1.27). Twenty four participants (88.89%) were of white-British ethnicity. Twenty one participants were recruited through the YOT, serving community sentences for convicted crimes, and six were recruited through the TYS. YOT and TYS participants had a 62.79% response rate.

Ten participants (27.21% of the sample population) were recruited from the HMP/YOI ranging from 18 to 25 years of age (*M* = 20.50, *SD* = 2.42). A total of 305 questionnaires and consent forms were distributed, 18 were returned (response rate = 5.90%). Ten of the eighteen participants who signed the consent form attended the research appointment (response rate = 55.56%; overall HMP/YOI response rate = 3.28%). Six participants (60.00%) were of black African or Caribbean ethnic background. The overall age range across the three research sites was 14 to 25 (*M* = 17.43, *SD* =2.49) and study response rate was 10.63%.

Justification of sample size based on power analysis.

Due to limited previous research and a lack of published (available) data on which to base power calculations, an estimate of power and sample size was derived using Cohen's (1988) "rule of thumb". Cohen's (1988) "rule of thumb" stipulates that: for a t-test with two independent groups, a Cohen's d of .2, .5 and .8, indicate small, medium and large effect sizes respectively; for ANOVA and ANCOVA calculations, partial eta-squared values of .01, .06 and .14, indicate small, medium and large effect sizes respectively. It is important to note that using a "rule of thumb" to calculate power is technically weaker than using effect sizes generated from previous research. Power was calculated using the power analysis programme G*Power (Faul, Erdfelder, Lang, & Buchner, 2007).

Hypothesis 1 aimed to compare the emotional accuracy mean scores of two groups (high dosage of TBI versus no or low TBI). The power calculation for hypothesis 1 estimated that for an independent t-test calculation, 64 participants per group (N = 128) would achieve 80% statistical power, a medium effect size (Cohen's d = 0.5) and an alpha of 0.05. Where it was appropriate to include covariates in the analysis (statistically and theoretically), ANCOVA was considered. Emotion recognition accuracy was entered as the dependent variable, group as the between subjects factor and the control measure subtest mean score as the covariate. It was estimated that for an ANCOVA calculation, 125 participants (64 per group) would achieve 80% statistical power, a medium effect size (f = 0.25; partial eta-squared = 0.06) and an alpha of 0.05.

Hypothesis 2 and hypothesis 3 aimed to compare emotion recognition bias within (emotion type, positive versus negative) and between groups (high dosage of TBI versus no or low dosage of TBI). In particular, a group by emotion type interaction was hypothesised for which hypotheses 2 and 3 require specific post hoc tests. This required a 2x2 mixed ANOVA. For a significant between-subjects effect, the power calculation revealed 98 participants (49 per group) would be required to achieve 80% statistical power, a medium effect size (f = 0.25; partial eta-squared = 0.06) and an alpha of 0.05, whereas for the within effect and the within-between interaction, 34 participants were required.

Due to the low response rates, the recommended participant numbers were not achieved. Consequently, this study is underpowered to detect significant within and between group differences with a medium effect size.

Measures

Descriptive information and TBI history.

Participants were asked to answer 5-12 descriptive questions with regards to ethnicity, gender, age, socio-economic status (SES), mental health and TBI history (appendix 1). With regards to TBI history, participants were asked 'Have you ever had an injury to the head that caused you to be knocked out and/or dazed and confused?' Participants were then asked to estimate the length of time they experienced a loss of consciousness (LOC) (dazed and confused without LOC (minor concussion); LOC < 10 minutes (mild TBI); LOC 10 – 30 minutes (complicated mild TBI); LOC 30 – 60 minutes (moderate TBI); LOC >60 minutes (severe TBI) and to provide information detailing frequency, age at injury, cause, and any medical attention received. The duration of LOC of their most severe injury was taken as a measure of TBI severity, and the frequency of their injuries was recorded. TBI classifications were based on the neurodisability section of the Community Comprehensive Health Assessment Tool (CHAT; Youth Justice Board, 2012) and studies by Williams et al. (2010) and Davies et al. (2012). A validation study of the TBI section of the CHAT has demonstrated good diagnostic accuracy (82%), sensitivity (78%) and specificity (82%; Chitsabesan et al., 2014). The recording of three levels of mild injury (minor concussion, mild TBI, complicated mild TBI) allowed for the determining of "dosage" of mild TBI consistent with European Federation of Neurological Society guidelines (Vos, et al., 2002). In support of this, Williams, Levin, and Eisenberg (1990) reported that those who suffered a complicated mild TBI experienced poorer neurobehavioural functioning outcomes compared to those with a mild TBI.

Wechsler Abbreviated Scale of Intelligence – Second addition (WASI-II): vocabulary and block design subtests.

Participants completed the vocabulary and block design subtests from the WASI-II (Wechsler, 2011). The vocabulary subtest measures verbal and general intelligence, language ability and memory. It required participants to define the meaning of 42 words that become progressively more difficult. The vocabulary subtest was chosen to control for verbal ability. A deficit in verbal ability has been shown to be related to poorer emotional processing performance (Baker, Peterson, Pulos, & Kirkland, 2014).

The block design subtest required participants to replicate thirteen 2D geometric patterns using a set of blocks within the given time-limit. The subtest measures perceptual and spatial organisation, visual-motor coordination and abstract conceptualisation (Wechsler, 2011). Research has suggested that reduced visuo-spatial skills are related to greater socio-emotional difficulties in children with brain injury (Tonks, Yates, Slater, Williams, & Frampton, 2009b). The block design test was therefore chosen to control for visuo-spatial ability.

There are no UK norms for the WASI- II. However, the American and UK Wechsler Adult Intelligence Scale IV (WAIS-IV; Wechsler, 2011) norms are the same. The WASI-II subtests have concurrent validity to the WAIS IV. Therefore, it can be assumed that the UK norms for the WASI-II are the same as the American norms (Wechsler, 2011).

Trail making tests A and B.

Participants were required to connect 25 targets as quickly and accurately as possible. Trail making test A required the sequential connection of numbers (e.g. 1, 2, 3). Part B required the sequential connection of numbers (1-13) and the alphabetical connection of letters (A-L), in an alternating pattern (e.g. 1, A, 2, B).

The tasks measure the participant's visual search and scanning abilities, processing speed, mental flexibility, task switching abilities and working memory (Tombaugh, 2004).

Emotional recognition task (ERT).

The ERT was developed by Penton-Voak and Munafo (2012). The task consists of a linear morph sequence of facial images that change incrementally from ambiguous to unambiguously happy, or unambiguously angry, or unambiguously surprised, or unambiguously fearful, or unambiguously disgusted, or unambiguously sad (Penton-Voak & Munafo, 2012). Each emotion contains 7 equally spaced images along the linear morphed sequence (e.g. ambiguous angry to unambiguous angry) (appendix 2). Participants were presented with 90 facial image trials in a random order displayed for 1500ms, preceded by a fixation cross (1500-2500ms) on an electronic tablet (Penton-Voak & Munafo, 2012). Following the presentation of the facial image, using the touch screen, the participant was required to select which emotion was displayed from one of the six emotional labels displayed on the screen (happy, surprise, angry, disgust, fear, sad) (Penton-Voak & Munafo (2012). No feedback was given. The output provides an emotion labelling accuracy total score, an individual emotion accuracy score and a false alarm score (the number of times the participant wrongly selected an emotion, which can be used as a measure of bias towards an emotion). Penton-Voak and Munafo are currently completing a large validation study for the ERT.

Procedure

Following ethical approval from the University of Exeter and the National Offender Management Service (appendix 4), permission was obtained from the three research sites to carry out the study. Data collection and procedural arrangements at the YOT and TYS was carried out by an MSc student (Cohen, 2014). Data collection and procedural arrangements at HMP/YOI was carried out by the author (for further information see appendix 8: procedure flow chart). Although some of the data collected was used for both an MSc project and a Doctorate in Clinical Psychology empirical paper, the research questions and hypotheses of the two studies were different. For example, Cohen (2014) did not investigate emotional bias. Furthermore, this study also included the addition of participants from the HMP/YOI and the age range differed from Cohen's (2014) study (14-25 years old and 14-19 years old, respectively).

Staff at each of the research sites identified eligible participants based on the inclusion and exclusion criteria (appendix 3). At the YOT and TYS, staff contacted eligible participants, provided them with details of the study (appendix 5) and determined interest in participation. For participants under the age of 16, the caregiver was required to provide consent. At HMP/YOI, eligible participants were sent a consent form (appendix 6) and questionnaire through the internal mail system and returned both forms to the wing complaints box. Signed consent forms were then collected by staff and returned to the researcher. The tasks were completed in a single 35-45 minute (approximate) session at a prearranged time, in a private interview room. Participants were supervised by the researcher throughout the session. Participants and caregivers were reminded that participation was entirely voluntary and that they were free to withdraw or be withdrawn from the study at any time. The tasks were administered in the following order:

1. Consent form sent to the participant, signed and returned to the researcher.
2. A paper demographic and TBI history questionnaire sent to the participant and completed independently or with support of the researcher at the prearranged session.
3. Emotion recognition task completed on an electronic tablet device.

4. Trails A and B tasks completed.
5. WASI-II vocabulary and block design subtests completed.

Following the completion of the task, participants were offered a verbal debrief and awarded a £5 high street voucher (YOT and TYS) or chocolate bar/healthy snack (HMP/YOI). All data was stored securely, kept anonymous and remained confidential.

Analysis Plan

Data analysis consisted of a number of within and between group comparisons. All data was tested for normal distribution. Where the sample was normally distributed, independent sample t-tests, ANOVAs and ANCOVAs were used to compare the within and between group means. Where the sample was nonparametric the data was transformed and normality was checked again. Where the data remained nonparametric following transformation, the Wilcoxon rank-sum and Mann-Whitney U tests were conducted to determine the significance of within and between groups respectively.

Previous studies have shown that facial-affect processing is associated with attention (Kohler, Bilker, Hagendoorn, Gur, & Gur, 2000), working memory (Kee, Kern, & Green, 1998), visual spatial abilities (Tonks et al., 2009b), verbal abilities (Barker et al. 2014) and executive functioning (Hoaken, Allaby, & Earle, 2007). Processing speed and age may also affect participant performance on computer tasks. In order to control for these variables, the WASI-II vocabulary subtest (verbal abilities), block design subtest (spatial abilities) and trail making tests A and B (attention, processing speed and executive functioning abilities) were undertaken. Correlation analysis was conducted between these tests and the DVs (overall emotional accuracy; recognition bias; appendix 9). Brace, Kemp and Snelgar’s

(2001) criterion was used to determine whether a covariate should be included in the analysis. According to Brace, Kemp and Snelgar (2001), an ANCOVA should be carried out if the correlation between the DV and subtest is >0.6. Where the criterion was met, ANCOVA calculations were undertaken. Where the criterion was not met, t-tests and ANOVA calculations were performed.

Results

Gender

The study sample contained a mixed gender population (24.32% female, N = 9; 75.68% male, N = 28). No significant gender effects were found for the between or within group analysis. Consequently, both male and female participants were included in all analyses.

Rates of TBI

Twenty three participants (62.16%) self reported a TBI (mild, moderate or severe; table 1). Within this group 12 participants (32.40% of the overall sample N=37) self-reported a mTBI and 11 participants (29.73% of the overall sample) self reported a moderate or severe TBI (table 2). Eight participants (21.62% of the overall sample N=37) reported a frequency of three or more TBIs. However, out of the eight participants, only two individuals had suffered multiple mTBIs, the remaining six had suffered at least one moderate-severe TBI and therefore already met the criteria for the TBI group. Within the sample (N=37) the prevalence rate of a moderate-severe TBI or three or more TBIs (high dosage TBI group) was 35.10% (N= 13).

Table 1

Self-reported severity of worst head injury

TBI severity	*n*	Percentage of sample
No history	14	37.8
Minor concussion	1	2.7
mTBI	9	24.3
Complicated mTBI	7	5.4
Moderate TBI	1	2.7
Severe TBI	10	27.0

Table 2

Frequency of self-reported head injury

TBI frequency	*n*	Percentage of sample
No history	14	37.8
1	8	21.6
2	7	18.9
3	2	5.4
4	1	2.7
> 4	5	13.5

Group Characteristics

Independent sample t-tests were conducted to investigate between group differences for age, the WASI-II vocabulary subtest, the block design subtest and trail making tests A and B. No significant between group differences were found (table 3), indicating that the subtest performances of high TBI dosage group were not worse than the no or low TBI group.

Table 3

Mean scores and between group differences for age, the WASI II vocabulary subtest, block design subtest and Trail making tests A and B.

Variable	**High TBI dosage**			**No or low TBI dosage**			***t***	***p***
	n	**Mean**	**SD**	***n***	**Mean**	**SD**		
Age	13	18.00	2.61	23	17.08	2.46	-1.04	0.30
WASI Block design T score	12	43.83	8.16	22	43.68	9.50	-0.05	0.96
WASI Vocabulary T score	13	36.46	11.50	22	39.64	12.67	0.74	0.46
Trail making A scaled score	12	0.83	0.25	21	0.60	0.37	-1.93	0.06
Trail making B scaled score	13	0.40	0.35	20	0.83	0.41	-0.11	0.91

Subtest Correlations

Correlation analysis was conducted to determine whether any of the subtest mean scores should be entered as a covariate when conducting calculations for hypotheses one, two and three. None of the correlations between the DV (overall emotional accuracy; recognition bias) and subtests were >0.6 and therefore did not meet Brace, Kemp and Snelgar’s (2001) inclusion criterion. This indicated that the identified variables (age, attention; working memory; visual spatial abilities; verbal abilities; processing speed) would not have a significant effect on the between and within group analyses. Therefore, no subtest scores where entered as covariates. Consequently, an independent t-test was carried out for hypothesis one and a 2x2 mixed ANOVA calculation was carried out for hypotheses two and three.

Emotional Recognition Accuracy

Hypothesis 1: Young offenders with a high dosage of TBI will be poorer at recognising/labelling facial emotions compared to offenders with no or low dosage of TBI.

An Independent Samples t-test was carried out to investigate between group overall facial recognition accuracy. Overall facial emotional recognition score for young adult offenders with a high dosage of TBI was not significantly worse (*M* =.48, *SD* = .10) compared to young adult offenders with no or low TBI (*M* =.53, *SD* = .10), $t(34) = 1.49$ $p = .15$, 95% CI [-.02, .12], Cohen's $d = 0.52$. This indicates that young adult offenders with a high dosage of TBI were not worse at recognising facial emotions compared to offenders with no or low TBI dosage.

Emotional Recognition Biases (Hypotheses 2 and 3)

In order to investigate hypotheses 2 and 3, a 2x2 mixed ANOVA for emotion recognition bias (false alarm selection) was carried out to check for a significant interaction between the within subject factor "emotion type" (positive; negative) and the between subjects factor "group"(TBI; no TBI). Although there was a significant main effect of emotion type $F(1,34) = 9.60$, $p = .04$, $\eta_p^2 = .22$, no significant main effect of group $F(1,34) = 1.51$, $p = .23$, $\eta_p^2 = .04$, or, crucially, no significant interaction between group and emotion type $F(1,34) = .34$, $p = .56$, CI [0.10, 0.11], $\eta_p^2 = .01$, were found. The significant main effect of emotion indicates that both groups showed higher levels of false alarms for positive emotions (*M* =.12, *SD* = .05) as compared to negative emotions (*M* =.08, *SD* = .03). The absence of a significant emotion by group interaction precludes further post-hoc tests and indicates that hypotheses 2 and 3 are not supported.

Discussion

This study's aim was to investigate whether young offenders with a high dosage of TBI show impaired facial emotion recognition and facial emotional bias, compared to offenders with no or low TBI. Within the study population, similar to rates described in previous studies (Davies et al., 2012; Williams et al., 2010), 62% of participants self-reported a TBI (mild, moderate or severe). Within the TBI group 32% of the overall sample self-reported an mTBI and 30% a moderate or severe TBI. The moderate-severe TBI rates reported within the sample are elevated compared to Williams et al.'s (2010) study (17%). Eight participants (22%) of the overall sample reported a frequency of three or more TBIs. Within the sample a 35% prevalence rate was found for 'high dosage of TBI', the severity and frequency of injury at which the literature suggests neuropsychological deficits are likely to occur (Collins et al., 1999; Croker & McDonald, 2005; Teasdale & Engberg, 2003; Wall et al., 2006, Williams et al., 2010).

On the basis of previous research it was hypothesised that those with a high dosage of TBI would be worse at recognising emotions compared to those with no or low TBI dosage (Tlustos et al., 2011; Tonks et al., 2007; Tonks et al., 2008). This was not supported. Overall facial emotion recognition accuracy was not significantly worse for young offenders with a high dosage of TBI compared to young offenders with a no or low TBI dosage. There are several possible explanations for this finding. First, the two groups in this study did not differ in any of the variables thought to contribute to facial emotional processing (e.g. attention; working memory; visual spatial abilities; verbal abilities; executive functioning). It is possible that given the cognitive abilities thought to "support" socio-emotional processing were found to be the same in both groups, it would be unlikely to have had differing outcomes for the emotional recognition task.

Second there may be a number of additional, and shared, risk factors for socio-emotional processing ability in the TBI and non-TBI offending groups of this study that may have confounded any issues relating to TBI (e.g. childhood abuse, parenting, childhood development; Rebellon & Gundy, 2005). However, these variables were not controlled for in this study and any such conclusions must be taken with caution. Indeed, this study did not have non-offender control groups (with and without TBI). These issues are discussed further in the limitations and future research sections below.

Third, the Penton-Voak and Munafo (2008) ERT task was chosen because it was thought that the additional complexities and time pressures were more reflective of real life emotional processing. However, in this instance, it may have been too complex and fast paced for the TBI and offender populations. Previous studies investigating facial emotion accuracy in TBI have used tasks that are dissimilar in a number of potentially important ways. Tonks et al. (2007) used the Florida Effect Battery (FAB; Bowers, Blonder & Heilman, 1999) to investigate facial recognition accuracy for children with a TBI. The FAB affect naming task requires verbal labelling of facial expression for 20 unambiguous images without a time limit. Whereas, the Penton-Voak and Munafo (2012) task displays morphed facial emotions ranging in ambiguity and has a time limit of 1500ms. Furthermore, the Penton-Voak and Munafo (2012) task includes the additional emotions “surprised” and “disgusted”. The two tasks, therefore, differ greatly in degrees of pressure (time) and complexity (number of emotions displayed; ambiguity of emotions). The author notes that the Penton-Voak and Munafo (2008) ERT task has not yet undergone a validation study for the general population and no research has been undertaken to determine its suitability for TBI or offender populations. Therefore, it might not be sensitive for detecting deficits experienced by individuals with a TBI and may not be a suitable task for TBI or young offender populations. The use of a standardised task, such as the FAB, could have been more appropriate and allowed comparison with other studies.

Fourth, this study had a small sample size (N=37) and only revealed a medium effect size (*d* = 0.52). This resulted in a lack of adequate statistical power, which makes the results of this study tenuous. Indeed, the small sample size means the results are very susceptible to a type 2 error. Type 2 error occurs when the null hypothesis is accepted, but is actually false. If the power of a study is adequate then the risk of type 2 error is decreased and conclusions can be drawn with greater confidence.

Hypotheses two was not supported by the results of this study. Young offenders with a high dosage of TBI did not show a bias towards negative facial emotions compared to positive facial emotions. Rather, there was a significant main effect of emotion indicating that both groups (young offenders with and without a high dosage of TBI) incorrectly selected neutral faces as positive significantly more than negative. These findings are not in keeping with Best et al.'s (2002) study which demonstrated that aggressive patients with an ABI were biased towards labelling neutral faces as negative. One explanation for this may be the participant's mood state at the time of testing. Schmid and Mast's (2010) study demonstrated that participants in happy moods showed a positive bias towards facial expressions. It may have been that the positive interaction with the researcher, change of environment (especially for incarcerated participants) and expectation of a reward (voucher or chocolate) primed participants to experience a positive mood. If this was the case, then the participant's positive mood may have affected their task performance and led to the observed positive bias. However, mood state was not measured during the task and therefore, drawing any conclusions about the effect of mood is not possible.

The ERT used in this study had greater time pressures and complexity (ambiguity of emotions displayed) compared to the task used by Best et al. (2002). This could explain the differing results in facial emotion bias. Furthermore, as discussed above, the Penton-Voak and Munafo (2012) task has not been validated for TBI or offender populations and may not be sensitive to the facial emotion bias processes experienced by these populations. Consequently, it is not possible to directly compare the results of the two tasks.

Hypothesis three was not supported by the results of this study. Young offenders with a high dosage of TBI did not demonstrate a significantly higher selection bias towards negative emotions when compared to young adult offenders with no or low TBI dosage. It could be that TBI does not significantly affect facial emotion bias within the offending population. However, for hypothesis three, the required sample size (98) to achieve 80% statistical power was not attained (N=37) and only a medium effect size was revealed (η_p^2= .04). Consequently, making any interpretations from the results of this study are highly tentative and should be taken with caution.

Application of the Results to the Social-Emotional Processing Stream (Ochsner, 2008)

The aim of this study was to investigate whether young adult offenders with TBI experience deficits in socio-emotional processing, and to integrate the findings into an existing model in order to guide the development of interventions and direct the improvement of custodial services. In particular, it was hypothesised that those with a higher dosage of TBI, would be associated with poorer emotion recognition accuracy (construct 2) and with a higher propensity to mistake neutral faces as negative (construct 1). It was thought that such deficits could underlie difficulties in socio-emotional behaviour that may lead to offending. However, neither hypothesis was supported. The results of the study did not support the constructs proposed by Ochsner's (2008) socio-emotional processing stream. Nonetheless, as discussed below, there are a number of limitations to this study. These would need to be addressed in future research before we are able to know whether or not the model was, or was not, appropriate for understanding socio-emotional processing in this population.

Limitations

The study contains several limitations which are discussed below.

Power calculation and estimated sample size.

The sample sizes for each of the hypotheses were estimated using Cohen's (1988) "rule of thumb" and not previous research. Therefore the basis of this study's power calculation is technically weaker than using effect sizes generated from previous research. Consequently, even if the estimated sample size was achieved, attaining a power value of 80% is not guaranteed if the obtained effect sizes are small and the study may still be susceptible to a type 2 error.

Achieved sample size.

The study had poor recruitment rates. The small sample size in combination with only medium (hypothesis 1: d = 0.52) or small effect sizes (hypotheses 2 and 3, emotion by group interaction: η_p^2= .01), resulted in inadequate statistical power. This prevents any conclusions being drawn from the results. Using the effect sizes obtained in this study, post hoc analysis indicated that in order to achieve 80% power, hypothesis 1 would require 120 participants and hypotheses 2 and 3 would require 138 participants.

Control groups.

The study did not have matched non-offender control groups (TBI and non-TBI). Consequently, it is not possible to compare the results to a non-offender population and determine the role of social emotional processing and TBI within the offender population. The lack of non-offender control groups limits the conclusions that could have been made and prevents the investigation of a direct association between TBI, emotional recognition and offending. Attaining adequate power and non-offender control groups could enable the identification of any underlying socio-emotional processing predictors.

Self-report.

The study relies on retrospective self-report for TBI history. Self-report requires the participant to have some level of insight into their deficits, which can be difficult following a TBI (Stancin et al., 2002). Furthermore, self-report allows participants to apply personal scales to answers that are not proportionally representative of the group as a whole. With this in mind, the self-report method employed in this study brings into question the reliability of the results with regards to certainty of TBI severity. Access to medical records and information from secondary sources (e.g. parents/peers) would allow information to be corroborated and increase the reliability of the information.

ERT validity.

The ERT (Penton-Voak & Munafo, 2012) used in this study has not undergone validity testing for TBI or offending populations. It is possible that given the aforementioned risk and predictive factors for socio-emotional processing, the task does not have adequate sensitivity or specificity to the emotional processes experienced by this population and is therefore not appropriate. The use of a validated emotional recognition task (e.g. the FAB) would enable conclusions to be drawn with greater confidence.

Measurement of visuo-spatial skills.

The WASI-II block design was used to measure visuo-spatial skills. However, previous research by Tonks et al. (2009a) investigating visuo-spatial skills and emotional processing used the Cube analysis and Dot discrimination tests from the Visual Object Space Perception task (VOSP; Warrington, James, 1991). There is no evidence to suggest that the two tasks are assessing the same cognitive processes. Consequently, if the block design mean score had met the criterion for inclusion in the analysis as a covariant, it would not have been possible to conclude the block design task was controlling for the same visuo-spatial processes identified by Tonks et al. (2009a). However, the block design did not meet the criterion for inclusion as a covariate and was not used in further analysis.

Additional risk factors for facial emotion processing difficulties and offending.

The existence of any significant background issues that may be additional risk factors of poor emotional recognition, TBI and offending were not addressed. These include: childhood abuse; family functioning; parenting; childhood development; socio-economic status. For example, research has shown that children who have been victims of physical abuse have a response bias towards angry facial expressions (Pollak & Sinha, 2002) and have a greater risk of violently offending (Rebellon & Gundy, 2005).

Mood state.

The task did not control for mood state during the session. It is possible that the participants mood state could affect their emotional biases, as found by Schmid and Mast's (2010) study. Measuring the participant's mood during the task may provide insight into the effect mood has on facial emotion recognition within the TBI and offender populations

Future research

Future research could seek to investigate whether a relationship exists between, brain injury, emotional processing and crime. Understanding the socio-emotional abilities of the offending population may add insight into whether specialist services and interventions are required to support rehabilitation.

It is important that future research achieves a large sample size and adequate statistical power to ensure that valid and robust conclusions can be made. Matched non-offender control groups are also required to allow comparisons to be made between offender and non-offender groups (with and without TBI) in relation to the factors that may be linked to socio-emotional processing. All groups should undertake an emotional processing task and cognitive subtest tasks (e.g. verbal, visuo-spatial, attention and executive functioning tasks) that are sensitive to the abilities of the population of interest. This would allow between group comparisons to be made. Furthermore, to enable comparisons with the results of previous papers, the selected tasks should include those used in other research (e.g. FAB; VOSP). In addition, self-report methods should be supported by secondary sources (e.g. medical records) to ensure that brain injury information is accurate. Family history, abuse and functioning should also be included as variables in future studies in order to account for any co-influence on TBI, emotional recognition abilities and offending. Measuring participant mood during the testing session would add insight into the effects of mood on emotional recognition and enable it to be controlled for during analysis. These additions would facilitate a more in-depth investigation into whether there is a link between TBI, socio-emotional processing and offending. Once more is known about whether a relationship exists between TBI, emotional processing and offending, future research could then aim to investigate if there is a suitable model available for this population.

Conclusions

Socio-emotional processing appears imperative for appropriate social functioning. Socio-emotional deficits may lead to inappropriate responses within social situations. Such actions could be detrimental to social functioning and may put an individual at greater risk of socially unacceptable behaviour (e.g. offending/re-offending). This study did not identify a difference between TBI and non-TBI offender groups for facial emotion accuracy or facial emotional bias. Contrary to previous research, the results indicated that offenders, with and without a TBI, showed a bias towards positive emotions. However, this study was a pilot and had several limitations. Without adequate power, a larger sample size, or control groups, it is difficult to draw any conclusions from the results of this study. Future research could address the limitations of this study and aim to investigate if a relationship exists between facial emotion recognition, TBI and offending.

In summary, on the basis of the results of this study, the use of Ochsner's (2008) model for the TBI and young offender population cannot be supported. If future research discovered that there was a link between TBI, socio-emotional processing and youth offending, it may then be reasonable to explore how these processes might be understood within a model. The identification and development of a suitable model could enable the clear representation of the cognitive and neural processes involved and allow the formulation of a heuristic that could support the identification of gaps within the literature and develop testable hypotheses.

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Appendix 1

Demographic and TBI history questionnaire

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Questionnaire

Demographics

1. What is your age?
2. What is your ethnic group?
3. What is your gender? (M/F)
4. What are the first 3 characters of your home post code (e.g. SW13)?

Head Injury Information

5. **Have you ever had a head injury to the head that caused you to be knocked out and/or dazed and confused, for a period of time? (E.g. from a fall, blow to the head, road traffic accident?)**

☐Yes ☐No

[If you answered ‘No’ to question ‘5’ please go to question ‘9’]
[Only answer this question if you answered ‘Yes’ to question ‘5’]

6. **How many times have you been knocked out and/or dazed and confused?**

☐ Once
☐ Twice
☐ Three times
☐ Four times
☐More than four times

If more than four times then how many?

[Only answer this question if you answered ‘Yes’ to question ‘5’]

7. **Please give details of the time(s) you have been knocked out and/or dazed and confused. (Tick the boxes for duration and cause and provide age at injury). For multiple injuries of same cause, label (1 = worst, 2, 3 etc.) and record all**

	Dazed or confused	**Unconscious for up to 5 minutes**	**Unconscious for 5 to 10 minutes**	**Unconscious for 10 to 20 minutes**	**Unconscious for 20 – 30 minutes**	**Unconscious for 30 to 60 minutes**	**Unconsciou for over 60 minutes (please indicate**
Road Accident							
Road accident in stolen car							
Fall when sober							
Fall when under the influence of drugs/alcohol							

injuries. For age and hospital visit information please reference the related injury)

Sports injury							
Fight							
Other non-criminal activity							
Other criminal activity							

[Only answer this question if you answered 'Yes' to question '5']

8. **After a being knocked out some people experience symptoms which can cause worry or be nuisance. We would like to know if you suffer from any of the symptoms given below. As many of these symptoms occur normally, we would like you to compare yourself now with how you were before being knocked out. Compared with before being knocked out, do you now (i.e., over the last 24 hours) surfer from:**

	Not experienced at all	No more of a problem	A mild problem	A moderate problem	A severe problem
Headaches					
Feelings of Dizziness					
Nausea and/or vomiting					
Forgetfulness, poor memory					
Poor concentration					
Confusion					
Fogginess (groggy feeling)					
Difficulty recalling everyday events					

Conviction(s)

9. What are you currently convicted for? [*all disclosures are voluntary*]

	None	Once	Twice	Three times	More than three
Burglary					
Shoplifting/theft					
Violent Offences					
Joyriding					
Fraud/deception					
Drug offences					
Sexual Offences					
Other					

If other please specify:

10. If your conviction
describing the injuries caused to the other parties [*all disclosures are voluntary*]:

☐ Assault without injury
☐ Minor Injury (e.g. bruises – minor or no medical treatment)
☐ Serious injury requiring hospital treatment (e.g. broken limb, stabbing, gunshot wound).
☐ Severe Injury (e.g. lasting impairment, life-threatening injury)
☐ Murder/Manslaughter
☐ Murder/Manslaughter of multiple victims

11. Please use the options below to record any previous convictions [*all disclosures are voluntary*]:

	None	Once	Twice	Three times	More than three
Burglary					
Shoplifting/theft					
Violent Offences					
Joyriding					
Fraud/deception					
Drug offences					
Sexual Offences					
Other					

Other:

If you have been previously convicted for a violent offence(s) please tick the boxes describing the injuries caused to the other party and on how many separate occasions you have been convicted for these injuries [*all disclosures are voluntary*]:

	Never	Once	Twice	Three Times	More than three (specify)
Assault without injury					
Minor Injury (e.g. bruises – minor or no medical treatment)					
Serious injury, requiring hospital treatment (e.g. broken limb, stabbing, gunshot wound).					
Severe Injury (e.g. lasting impairment, life-threatening injury)					
Murder/Manslaughter					
Murder/Manslaughter of multiple victims					

Please record your age at previous conviction(s):

THAT IS THE END OF THE QUESTIONNAIRE
THANK YOU VERY MUCH

What next?
Please place the completed questionnaire and consent form in the envelope provided (addressed to Jac Dendle) and place in the wing complaints mail box

Appendix 2

Emotional recognition task face continuum example

An example of 3 images from Penton-Voak et al.'s (2012) emotion recognition task, morphing from emotionally ambiguous to angry.

Appendix 3

Inclusion and exclusion criteria

Table 4

Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Aged 15-18 years old	Known learning disability (e.g. Autistic Spectrum Disorders or Down's Syndrome).
Currently detained in Ashfield Young Offenders Institute	Pupils whose English comprehension is limited. This is to make sure that participants are capable of understanding and responding to task instructions and questions.
	Moderate to severe mental health problems.

Appendix 4

Ethical approval documentation

Psychology Research Ethics Committee

Psychology, College of Life & Environmental Sciences

Washington Singer Laboratories
Perry Road
Exeter
EX4 4QG

Telephone +44 (0)1392 724611
Fax +44 (0)1392 724623
Email Marilyn.evans@exeter.ac.uk

To: **Jac Dendle**
From: **Cris Burgess**
CC:
Re: **Application 2013/ 360 Ethics Committee**
Date: **March 7, 2017**

The School of Psychology Ethics Committee has now discussed your application, ***2013/360 – Socio-emotional processing in young adult offenders with traumatic brain injury.*** The project has been approved in principle for the duration of your study.

The agreement of the Committee is subject to your compliance with the British Psychological Society Code of Conduct and the University of Exeter procedures for data protection (http://www.ex.ac.uk/admin/academic/datapro/). In any correspondence with the Ethics Committee about this application, please quote the reference number above.

I wish you every success with your research.

Cris Burgess
Chair of Psychology Research Ethics Committee

HM Prison Service
Greater London Psychological
Services (GLPS)
c/o HMP Holloway
1X Parkhurst Road
LONDON
N7 0NU

Ministry of JUSTICE
National Offender Management Service

Telephone: 020 7979 4618
Email: claire.smith@hmps.gsi.gov.uk

Jac Rhys Dendle

7 March 20174

Dear Jac,

Research Title: Socio-emotional processing in young offenders with Traumatic Brain Injury

Please accept this letter as confirmation that your application to conduct research at HMP & YOI Isis has been approved in line with PSI 13/2012. However, I must make you aware of a number of conditions that have been applied:

- A copy of the final research report must be sent to the Governor of HMP Isis and the Lead Psychologist for Greater London (Ms Toni Mason).
- The findings should be shared with the Senior Management Team at HMP Isis
- The findings of the research should only be published with the permission of the Governor of HMP Isis and/or the Lead Psychologist for Greater London. This decision will be made <u>AFTER</u> the findings are known and the project report is completed (this does not include the final dissertation report).
- This letter does not commit any staff and/or resources from HMYOI Isis; this issue should be discussed directly with managers at the prison.

- This letter does not give approval to take electronic equipment (i.e. a Laptop) into HMP Isis. In order to use such equipment, permission must be sought from the security department at HMP Isis.
- The research must comply with The Data Protection Act and all NOMS information assurance protocols
- At the end of the project the researcher must prepare a research summary for the NOMS National Research Committee and the Regional Psychology Lead (approximately three pages; maximum of five pages) which (i) summarises the research aims and approach, (ii) highlights the key findings, and (iii) sets out the implications for NOMS decision-makers. It must be submitted to the NRC alongside the NRC project review form (which covers lessons learnt and asks for ratings on key questions). Provision of the research summary and project review form is essential if the research is to be of real use to NOMS. The report must use language that a lay person would understand. It must be concise, well organised and self-contained. The conclusions must be impartial and adequately supported by the research findings.

Please let me know if you require any further information and good luck with your research.

Regards,

Sent by email – no hard copy to follow

Claire Smith, C.Psychol, AFBPsS
Registered and Chartered (Forensic) Psychologist
Cluster Lead Psychologist Greater London

Appendix 5

Information sheet

School of Psychology

Study: Socio-emotional processing in young adult offenders with traumatic brain injury

STUDY INFORMATION SHEET

We are inviting you to participate in a research study run by the School of Psychology at the University of Exeter. The aim is to investigate how well you recognise other people's emotions by looking at their faces. Before you decide to participate or not, it is important for you to understand why the research is being done and what it will involve. Therefore, please read this information.

The purpose of this study

There is a relatively small amount of research investigating how good young adult offenders with Traumatic Brain Injury (TBI) are at recognising other people's emotions by looking at their faces. Being able to recognise emotions is extremely important for interacting with people and finding it difficult may lead to misunderstandings and socially unacceptable behaviours. The study could potentially add more vital insight into how well young adult offenders with TBI can identify facial emotions. Identifying any weaknesses in recognising emotions will help the development of specialist interventions and direct the improvement of the services.

Risks and Benefits of Participating

You do not have to take part. However, by taking part you will help us to better understand how good young adult offenders with TBI are at recognising peoples emotions by looking at their faces. Should you decide to take part, you can withdraw from the research at anytime without providing a reason.

What would the study involve?

The study involves attending a 45 minute session in HMP/YOI Isis health care centre with a researcher, in which you will complete a short questionnaire asking you about any head injuries you may have had and your conviction(s), a 10 minute computer programme involving recognising people's emotions by looking at the faces and 4 short tasks. In addition, you are asked to sign the consent form.

How would I complete the questionnaire?

If you wish to participate you must sign the consent form and place it in the wing complaints mail box in the envelope provided (addressed to Jac Dendle).

A time will then be organised for you to attend a session with the researcher to complete a questionnaire, a computer task and 4 short additional tasks. This will take place in the HMP/YOI Isis health care centre and will last about 45 minutes.

Will the study be confidential? Will it be possible to identify me?

All information will be kept strictly confidential. It will be coded so that your information will be made anonymous (i.e., your consent form and any personal details such as your name will be separated from the questionnaires and stored separately). It will not be possible to identify you.

We have to note that if you were to tell us that you were seriously intending to harm yourself or another person, or that you were engaged in, or planning to, engage in a serious criminal act, we would be duty bound to report such activities to the relevant authorities.

The results of the study

When we have completed our study the results will be written up as part of the researcher's Doctorate in Clinical Psychology at the University of Exeter. We would also submit the write-up to an academic journal. The information would be reported in a way that it would not be possible to identify you.

What is in it for me?

If you sign the consent form and participate in the study you will receive the option of a ***healthy snack*** or ***chocolate bar****.*

Who is running the study?
The research forms part of a programme of work conducted by the Centre for Clinical Neuropsychology Research (CCNR, co-directed by Professor Huw Williams, Dr Anna Adlam, and Dr Phil Yates).

What to do if you have any questions?

If you would like any information or advice on head injury and concussion, please contact:

Jac Dendle
University of Exeter
College of Life and Environmental Sciences
Washington Singer Laboratories
Prince of Wales Road
Exeter
Devon
EX4 4QG

Researcher: Jac Dendle

Supervisor:

Prof. W. Huw Williams
Associate Professor in Clinical Neuropsychology
University of Exeter

Appendix 6

Consent form

University of Exeter
School of Psychology

Consent Form

Study: Socio-emotional processing in young adult offenders with traumatic brain injury

1) I have read and understood the study information sheet.
2) I am satisfied with the amount of information I have been given about this research.
3) Any questions I had have been answered to my satisfaction.
4) I understand I am free to withdraw from this study at any time, without giving a reason.
5) I agree to take part in this research.

☐ Please tick this box below if you wish to be contacted about participating in other research projects conducted by the CCNR.

By ticking the box above you are agreeing to the following:
I am happy for my name and details (date of birth, age at injury, nature of injury) to be kept on a secure (encrypted and password protected) research volunteer database at the School of Psychology, University of Exeter. I understand that my contact details will only be accessed by members of the Centre for Clinical Neuropsychology Research (CCNR, co-directed by Professor Huw Williams, Dr Anna Adlam, and Dr Phil Yates). I understand that I will only be contacted about CCNR research studies that have appropriate ethical approval. I understand that I am not obliged to participate in these studies and that I will be invited to participate in no more than 3 studies in 5 years. I understand that I can withdraw my consent to store my contact details at any time, without giving a reason, and without any clinical care that I, may receive being affected.

Name (please print clearly in block capital letters)

....

Signature………………………………… Date…………………………

Appendix 7

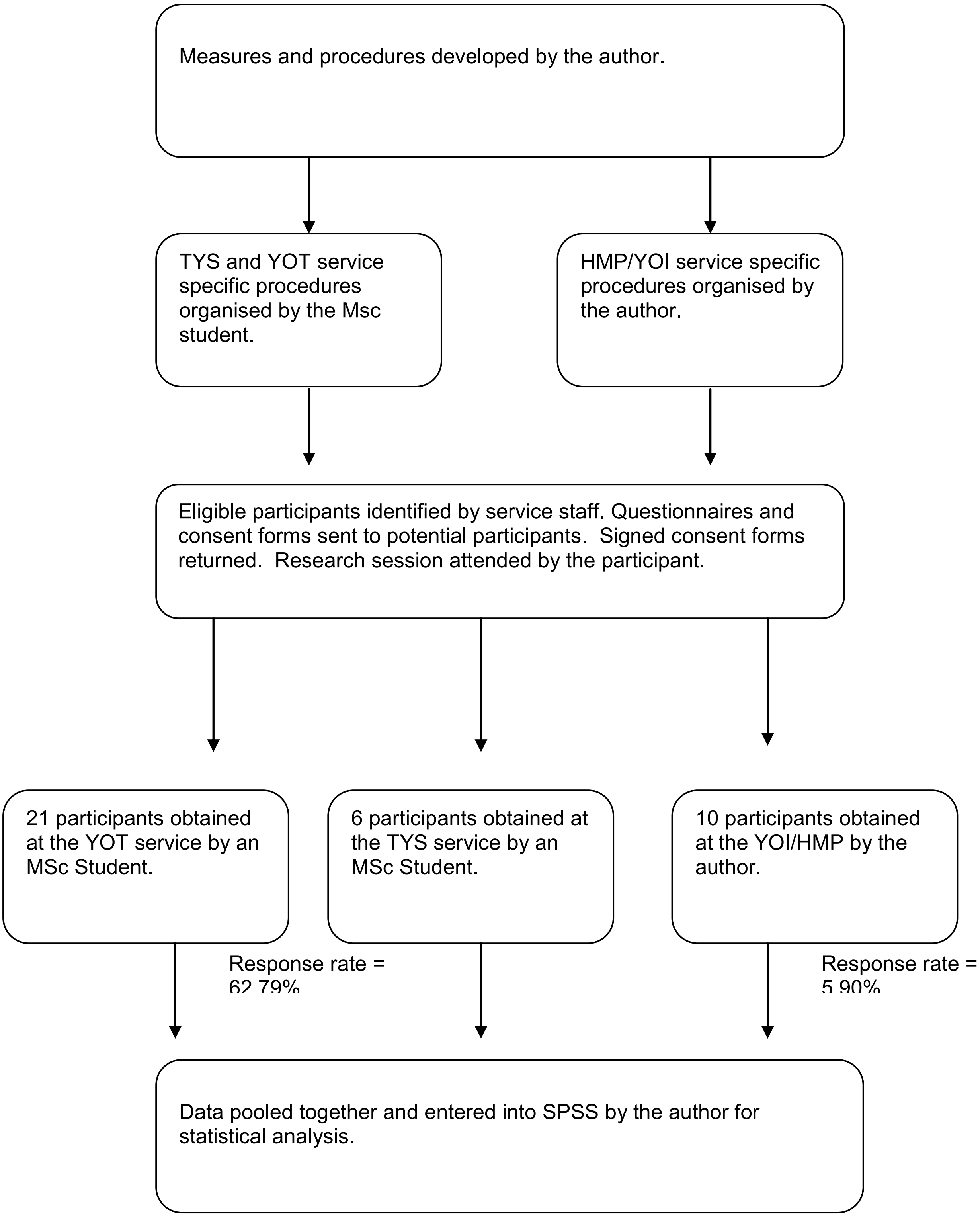
Dissemination statement

It is intended that the results of the study will be disseminated in the following manner:

- Publication: Journal of head Trauma Rehabilitation.
- Neuropsychology conferences – to be discussed with the study supervisor and confirmed.
- Presentation to the participating research sites and staff teams.

Appendix 8

A flow chart displaying the data collection processes across the three research sites



Appendix 9

Table of the correlations between the DV and the WASI-II vocabulary subtest, the block design subtest and trail making A and B.

Table 4

Correlations between the dependent variable and the WASI-II vocabulary subtest, the block design s

Subtest		**Dependent variable**		
		Overall emotional recognition	**Positive facial recog.**	**Negative facial recog.**
Age	Significance	0.23	0.24	0.30
	Pearson Correlation	0.21	0.20	0.18
WASI II Vocabulary standardised t	Significance	0.01	0.00	0.18
	Pearson Correlation	0.41	0.53	0.23
WASI II Block Design standardised t	Significance	0.23	0.03	0.80
	Pearson Correlation	0.21	0.37	-0.04
Trail making A scaled score	Significance	0.52	0.47	0.84
	Pearson Correlation	-0.12	-0.13	-0.04
Trail making B scaled score	Significance	0.55	0.97	0.53
	Pearson Correlation	-0.11	-0.01	-0.12

Appendix 10

Journal of Head Trauma Rehabilitation: Information for authors

Authors should pay particular attention to the following items before submitting their manuscripts:

Manuscript Preparation

- *JHTR* uses the *American Medical Association Manual of Style*, 10th edition.
- *JHTR* requires authors to use person-first language—avoid phrasing such as “the brain-injured participant”or the “TBI patient”and replace with “participant with a brain injury” or “patient with a TBI.”
- Manuscripts should be line numbered in their original format (eg, Microsoft Word line numbering).
- Manuscripts should be double-spaced, including quotations, lists, references, footnotes, figure captions, and all parts of tables. Do not embed tables in the text.
- Manuscripts should be ordered as follows: title page, abstracts, text, references, appendices, tables, and any illustrations.
- To maintain a masked review process, it is the author’s responsibility to make every attempt to mask all information in the manuscript that would reveal the identity of the author to the reviewer. This version of the manuscript is referred to as the “masked” manuscript when uploading documents.
- Title page including (1) title of the article; (2) author names (with highest academic degrees) and affiliations (including titles, departments, and name and location of institutions of primary employment); (3) all possible conflicts of interest including financial, consultant, institutional, and other relationships that might lead to bias or a conflict of interest; (4) disclosure of funding received for this work including from any of the following organizations with public or open access policies: National Institutes of Health (NIH), Wellcome Trust, and the Howard Hughes Medical Institute; and (5) any acknowledgments, credits, or disclaimers.
- A structured abstract of no more than 200 words should be prepared. Authors should use telegraphic language where possible, including omission of

introductory clauses. Headings should typically include the following: Objective, Setting, Participants, Design, Main Measures, Results, and Conclusion. The Conclusion section should encapsulate the clinical implications of the results, not merely restate the findings.

- Include up to 10 key words that describe the contents of the article such as those that appear in the Cumulative Index to Nursing and Allied Health Literature (CINAHL) or the National Library of Medicine's (NLM's) Medical Subject Headings (MeSH).
- There should be a clear indication of the placement of all tables and figures in text.
- The author is responsible for obtaining written permission for any borrowed text, tables, or figures.

References

- References must be cited in text and styled in the reference list according to the *American Medical Association Manual of Style*, 9th edition, copyright 1998 American Medical Association. They must be numbered consecutively in the order they are cited and listed in that sequence (not alphabetically); reference numbers may be used more than once throughout an article. Page numbers should appear with the text citation following a specific quote. References should be double-spaced and placed at the end of the text.
- References should not be created using Microsoft Word's automatic footnote/endnote feature.

Figures

Color Figures

JHTR is a black and white publication and figures will be printed in black and white. It is possible, however, for figures to be printed in full color (4 color) either at the discretion of the editor or with a per-page fee of $650. If you would like to have your figures printed in color, please contact John Corrigan, Editor (e-mail: corrigan.1@osu.edu).

Tables Tables should be on a separate page at the end of the manuscript. Number tables consecutively and supplies a brief title for each. Include explanatory footnotes for all nonstandard abbreviations. Cite each table in the text in consecutive order. If you use data from another published or unpublished source, obtain permission and acknowledge fully.

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